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OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Lieut. William Gordon Bennett, R.N.R., Edleston, Battenhall, Worcester;

R. T. Crawford, Ph.D., Associate Professor of Practical Astronomy in the Berkeley Astronomical Department of the University of California, Berkeley, Cal., U.S.A.;

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John Jackson, M.A., B.Sc., Trinity College, Cambridge;

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John Hall Rider, M.Inst.C.E., P.O. Box 149, Johannesburg, South Africa;

Robert Rossi, M.Sc., Trinity College, Cambridge;

Thomas Royds, D.Sc., Assistant Director, Kodaikánal Observatory, India;
William James Simmons, 8/2 Hastings Street, Calcutta, India;
Rev. Oliver Rowland Walkey, 11 Grange Road, Chiswick, W.;
Thomas Petty Witter, Aymestry, 57 Scarisbrick New Road, Southport, Lancashire; and
Harry Thomas Wright, A.R.C.Sc. (Lond.), Engineering College, Täng Shan, near Tientsin, N. China,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Herbert F. Acocks, Fernyhurst, Ashtead, Surrey (proposed by the Rev. T. E. R. Phillips); and
Arthur Dallas, Civil Engineer and Architect, Vice-President of the Institute of Architects in China, etc., 4 Peking Road, Shanghai (proposed by M. W. Campbell Hepworth).

Sixty-six presents were announced as having been received since the last meeting, including, amongst others:—
Twenty boxes of plates (negatives, etc.) taken by the late Mr. George Dunn, presented by his Executors.
Portrait of Sir W. H. M. Christie (heliogravure from painting by Jacomb-Hood), presented by Sir William Christie.

On the Periodic Errors in the Right Ascensions of the Standard Catalogues. By S. S. Hough, M.A., F.R.S., H.M. Astronomer at the Cape.

The new Cape Transit Circle has been in use throughout the years 1905–11 for the purpose of forming a "fundamental" catalogue of stars distributed throughout those regions of the sky which culminate above the Cape horizon.

The derived right ascensions of the stars have been provisionally referred to the "adopted" positions of 267 stars selected as "clock" stars approximately uniform in magnitude and symmetrically distributed near the equator, as indicated in the following table:—

TABLE I.

Distribution of Clock Stars.

Limits of R.A.	Mean Dec.	Mean Mag.	No. of Stars.	Limits of R.A.	Mean Dec.	Mean Mag.	No. of Stars.
h h	°			h h	°		
0 – 1	– 1	4·6	11	12 – 13	+ 1	4·0	10
1 – 2	– 1	3·9	11	13 – 14	– 3	4·3	9
2 – 3	0	4·4	15	14 – 15	– 2	4·7	11
3 – 4	+ 4	4·0	14	15 – 16	– 4	3·9	13
4 – 5	+ 8	4·2	12	16 – 17	+ 6	3·6	8
5 – 6	– 4	3·1	11	17 – 18	– 5	3·6	10
6 – 7	+ 3	4·1	13	18 – 19	– 3	3·9	11
7 – 8	+ 4	4·0	9	19 – 20	0	4·1	13
8 – 9	+ 3	4·2	11	20 – 21	+ 4	4·1	10
9 – 10	+ 4	4·6	9	21 – 22	– 4	3·9	12
10 – 11	0	4·8	11	22 – 23	0	3·8	12
11 – 12	+ 3	4·0	10	23 – 0	+ 3	4·5	11

The observations for purposes of the catalogue have, as a rule, been distributed in "watches" of not more than four hours' duration, all the observations of a watch being made by the same observer. The mean clock error for each watch has been derived from the mean of all the observations of stars contained in the clock-star list, which are included among the stars observed in the watch, a minimum of five such stars being usually observed on each occasion.

The actual clock error applied to each observation is derived from this mean clock error, extended to the actual time of observation by the assumption that the rate of the clock is uniform throughout the watch. The adopted rate is, however, derived, not from the variations which present themselves within the watch, but from a comparison of the mean clock error of a watch with that of adjacent watches on the preceding or following days; or, in some cases, from the mean of such determinations extending over several days.

The clock errors thus derived have been applied to the observed times of transit in the journals, and the results for the separate stars collected in ledgers, the derived right ascensions of the clock stars, however, not being ledgered unless at least four other clock stars are observed in the same watch.

The final right ascensions of the stars are derived from the mean of the separate entries in the ledger for each star.

It is evident that while this process will tend to produce a system of right ascensions freed from the accidental errors of the adopted tabular places, the systematic errors, in so far as they are dependent on the R.A. of the stars, will, on account of the short duration of the watches, be reproduced almost in their entirety in the resulting positions.

Thus, if we compare the results obtained in the ledgers with the standard positions of Newcomb, Boss, and Auwers, through the medium of these clock stars combined in groups of three hours, we obtain the following results :—

TABLE II.

Comparison of Cape Ledgers with the Standard Systems of Newcomb, Boss, and Auwers.

	$\Delta\alpha$ (*Cape Ledgers – Catalogue compared*).		
Mean R.A.	Newcomb.	Boss.	Auwers.
h	s	s	s
0	−0·0004	+0·0050	+0·0005
3	+ ·0006	+ ·0057	+ ·0067
6	− ·0064	+ ·0029	+ ·0011
9	+ ·0036	+ ·0090	+ ·0040
12	+ ·0002	+ ·0009	− ·0010
15	− ·0033	− ·0034	− ·0048
18	+ ·0043	− ·0013	+ ·0015
21	− ·0002	+ ·0039	− ·0002

Giving equal weight to each one of these quantities, and assuming that the discordances may be expressed by an analytical formula of the form

$$\Delta\alpha = a + b\cos\alpha + c\sin\alpha + d\cos 2\alpha + e\sin 2\alpha,$$

we derive the following numerical expressions for the discordances :—

Cape Ledgers – Newcomb

$$= -0^s\cdot0002 - 0^s\cdot0002\cos\alpha - 0^s\cdot0013\sin\alpha + 0^s\cdot0005\cos 2\alpha + 0^s.0000\sin 2\alpha,$$

Cape Ledgers – Boss

$$= +0^s\cdot0028 + 0^s\cdot0018\cos\alpha + 0^s\cdot0035\sin\alpha + 0^s\cdot0011\cos 2\alpha - 0^s\cdot0027\sin 2\alpha,$$

Cape Ledgers – Auwers

$$= +0^s\cdot0010 + 0^s\cdot0017\cos\alpha + 0^s\cdot0027\sin\alpha + 0^s\cdot0008\sin 2\alpha - 0^s\cdot0005\sin 2\alpha\,;$$

while the sums of the squares of the residuals resulting from the three comparisons, expressed in units of the fourth decimal place, amount to 7607, 1702, 4429.

It thus appears that the Cape Ledger results, after removal of the systematic discordances of the character supposed, give a better agreement with the predictions of Boss and Auwers than with those of Newcomb. These systematic discordances are, however, themselves always small, especially in the case of the comparison with Newcomb. This result is to be expected, as Newcomb's data have been adopted as the initial basis of the

ledgers. But it follows that any such systematic corrections to the system of the Cape Ledgers which may be derived, will apply with only slight modifications to the standard systems of Newcomb, Auwers, and Boss at the same epoch.

To afford a means of investigating these corrections, regular observations of the Sun and of the bright stars have been made by daylight, in addition to the night observations, which form the primary basis of the ledgers. The determinations of the absolute zero of right ascension, which will depend on the observations of declination of the Sun as well as of its R.A., have not yet been undertaken, but the observations of R.A. of the daylight stars have been discussed with a view to the determination of the periodic errors of the system.

In addition to the brighter stars of the clock-star list, some thirty-three additional bright stars have been more or less frequently utilized for daylight observations. These stars, while not utilized for determination of clock error in the ordinary night watches, have been observed frequently in the ordinary course of observing, and their places derived in the ledgers.

With the places obtained from the ledgers, clock errors have been derived at the instant of each daylight transit, and the results compared with those interpolated from adjacent night watches, with clock rates derived from intervals of approximately twenty-four hours, or a multiple thereof.

On tabulating the results it was at once apparent that the difference in the clock errors obtained by day observations, as compared with those obtained by night observations, presented a pronounced periodic discordance, the difference (*Day – Night*) having a maximum about the middle of each year, and a minimum near the months of December and January.

The investigation of the discordance has been made to depend on the day observations made since May 1908, when a new clock by Riefler, in an air-tight case, and installed in a chamber protected against temperature variations, was brought into use. Assuming that the tabular right ascensions of the clock stars, apart from errors of the equinox, are affected by an error which can be expressed analytically by the formula

$$A_1 \cos \alpha + B_1 \sin \alpha + A_2 \cos 2\alpha + B_2 \sin 2\alpha,$$

an equation of condition from each day observation was formed by equating the expression

$$K + A_1(\cos \alpha_1 - \cos \alpha_2) + B_1(\sin \alpha_1 - \sin \alpha_2) + A_2(\cos 2\alpha_1 - \cos 2\alpha_2) + B_2(\sin 2\alpha_1 - \sin 2\alpha_2)$$

to the differences in the clock correction obtained by day and by night, in the sense Day – Night; α_1 here denotes the R.A. of the day star, and α_2 the mean R.A. of the night stars on which the comparison depends.

The constant term K is introduced as representing either a constant difference in personality between day and night observing, or a regular diurnal periodicity of the clock.

In view of the former interpretation the results derived by each different observer have been separately grouped, and no assumption has been made as to the identity of the "constant" elements in the various groups. The personal differences in the night observations have been elsewhere examined, but found to be insignificant.

The equations thus formed have been solved by least squares, giving equal weight to each equation with the following outcome, in which the results obtained from separate years are independently presented as well as the result from the combination of the four-years' observations.

TABLE III.

Coefficients of Periodic Errors in Clock-Star System.

Year of Observation.	A_1.	B_1.	A_2.	B_2.
	s	s	s	s
1908	−0·0057	+0·0122	−0·0155	−0·0046
1909	+ ·0020	+ ·0177	− ·0005	+ ·0047
1910	− ·0149	+ ·0165	− ·0103	+ ·0010
1911	− ·0090	+ ·0122	− ·0148	− ·0069
1908–11	− ·0085	+ ·0148	− ·0103	+ ·0006
	± ·0009	± ·0008	± ·0011	± ·0012

The probable errors shown at the foot of each column are those which result from the least square solution, the derived probable error corresponding with unit weight, which depends on a comparison of a single daylight observation with a group of night observations involving as a rule not less than five stars, amounting to $\pm 0^s{\cdot}031$.

The agreement of the separate results in the same vertical column does not confirm the degree of precision of the mean results indicated by these probable errors, and suggests that further causes of systematic error may have been operative; it, however, leaves but little doubt as to the results not being mere accidental errors of observation, but pointing either to some unrecognized source of systematic discrepancy in the observations themselves or to a real periodic error in the data on which the Cape Ledger system has been based; and this, as established above, if it exists, is shared by the standard systems of Newcomb, Boss, and Auwers.

In further estimating the reliability of the results it is of interest to examine the constant element K, which has been introduced into the equations of condition. The derived values for the different observers are exhibited in the following table of personal differences between the day and night observations:—

TABLE IV.

Discordances between Day and Night Determinations of Clock Error (in sense Day – Night), grouped according to Observers.

Day Observer.	Years of Observation.									
	1908.		1909.		1910.		1908–10.		1911.	
*	s		s		s		s	s	s	s
C.	+0·005		0·000		+0·004		+0·002	±0·003	0·000	±0·005
A.P.	– ·026		– ·021		+ ·012		+ ·010	± ·003	+ ·050	± ·006
R.C.	– ·007		– ·002		+ ·017		+ ·005	± ·004	+ ·004	± ·006
A.W.	+ ·004		+ ·018		+ ·033		+ ·020	± ·003	+ ·021	± ·004
M.	– ·019		– ·023		– ·024		– ·022	± ·003	+ ·014	± ·006
J.J.	+ ·012		+ ·009		+ ·023		+ ·012	± ·003	+ ·013	± ·005
J.W.	– ·008		– ·009		– ·012		– ·010	± ·004		
S.									– ·024	± ·012
Mean	– ·0056		– ·0040		+ ·0076		– ·0004		+0·0110	

The results for the year 1911 are separately presented, as the method of observing employed in this year differs from that in the previous years. The observations throughout have been made with a Repsold travelling wire micrometer, which doubtless accounts for the small differences in personality as compared with what might have been expected from the older methods of observing by either "eye and ear" or "chronograph records" taken over fixed wires. During 1911, however, the travelling wire has been driven by a mechanical movement at a speed approximately corresponding with that of the object under observation, the exact coincidence of the travelling wire with the star being maintained throughout the observation by means of a delicate tangent screw. In the previous years the maintenance was secured purely by the method of hand guiding.

As these discordances may be attributed to systematic diurnal irregularities of the clock in combination with personality of observing, the simple means are exhibited at the foot of each vertical column. Even in the most unfavourable case the apparent semi-amplitude of the diurnal variation in the clock correction does not exceed $0^{s}\cdot0055$, while from the mean of the four years it amounts only to $0^{s}\cdot0012$.

To account for the discordances of Table III. by systematic irregularities of the clock would require not merely that these irregularities should exceed the value here found in a ratio of about ten to one, but also that their extreme values should regularly recur with reversed sign as between summer and winter.

Further sources of systematic discrepancy, such as dependence

* The initials indicate the following observers :—C. = Mr. W. H. Cox ; A.P. = Mr. J. A. J. Pead ; R.C. = Mr. R. W. Cheeseman ; A.W. = Mr. A. J. Wilkin ; M. = Mr. H. F. Mullis ; J.J. = Mr. J. W. Jackson ; J.W. = Mr. J. C. Wood ; S. = Mr. F. H. Scragg.

on the declination or on the magnitude of the stars utilized, have been examined, but with the general conclusion that the periodic corrections above derived will not be materially affected.

Thus, on the evidence of the daylight observations the conclusion is derived that, in order to reduce the results in the Cape Ledgers to an absolute system, the following periodic corrections are required:—

$$+0^{s}\cdot0085\cos\alpha - 0^{s}\cdot0148\sin\alpha + 0^{s}\cdot0103\cos 2\alpha - 0^{s}\cdot0006\sin 2\alpha.$$

A verification of this result has been sought from comparison with recent observations made in other observatories. On account of the uncertainty attaching to the proper motions of the stars it is of course necessary to limit the comparison to observations at or near the same epoch, and further, to results for which an attempt has been made to secure an "absolute" basis.

In the first instance, a comparison was effected with the star places derived by Nyrén from observations at Odessa* between the years 1899–1903, the Cape observations being reduced to the epoch 1900 with Newcomb's proper motions, those of Odessa with the proper motions of Auwers

A similar comparison was subsequently made with the results obtained at Pulkovo for the equinox 1905·0 from observations between 1903–1909, as communicated by Jaschnow.†

In both these series a limited number of fundamental stars have been employed, of which twenty-four only are included in the Cape Ledgers. The time stars are somewhat more widely distributed in declination than those used for the same purpose at the Cape. Consequently, in effecting the comparison it has been thought advisable to introduce a term (D) depending on the declination, and for greater completeness a further term (M) depending on magnitude has been introduced. Thus the differences $\Delta\alpha$ (*Cape – Pulkovo* or *Cape – Odessa* have been assumed to be of the form

$$\Delta E + A_1\cos\alpha + B_1\sin\alpha + A_2\cos 2\alpha + B_2\sin 2\alpha + D\frac{\delta}{10} + M(m - 2\cdot0),$$

where ΔE denotes a constant difference in equinox, δ the declination expressed in degrees and m the magnitude of the star. Equations of condition were formed for each star by equating this expression to the difference, *Cape – Pulkovo* or *Cape – Odessa*, the Pulkovo and Odessa right ascensions being obtained by application of the corrections derived by Jaschnow and Nyrén respectively to the tabular positions of Auwers.

Giving equal weight to each of these equations, the solution by least squares yielded the following results:—

* *Publications de l'Observatoire Central Nicolas*, vol. xix. The comparisons with Odessa are based on the revised data supplied by M. Nyrén.

† *Mitteilungen der Nicolai Hauptsternwarte zu Pulkovo*, Band IV. 12.

Cape – Pulkovo

$$+0^s\cdot0084 - 0^s\cdot0038\cos\alpha + 0^s\cdot0092\sin\alpha - 0^s\cdot0093\cos 2\alpha - 0^s\cdot0043\sin 2\alpha - 0^s\cdot0029\left(\frac{\delta}{10}\right) + 0^s\cdot00133(m - 2\cdot0),$$

Cape – Odessa

$$+0^s\cdot0150 - 0^s\cdot0042\cos\alpha + 0^s\cdot0129\sin\alpha - 0^s\cdot0043\cos 2\alpha + 0^s\cdot0004\sin 2\alpha - 0^s\cdot0068\left(\frac{\delta}{10}\right) + 0^s\cdot0009(m - 2\cdot0).$$

While these results tend to confirm the general character of the discordances, on account of the limited number of stars used, they are not entitled to any great weight, their chief importance being due to the fact that the Pulkovo and Odessa results have been reduced on a strictly fundamental basis.

The comparison with Odessa may be strengthened by utilizing an additional number of stars from the body of the Catalogue. Thus, from seventy-eight stars common to the Odessa Catalogue and the Cape Ledgers, grouped in three-hourly groups, we find:—

$\Delta\alpha$ (*Cape – Odessa.*)

h	s	No. of Stars.
0	−0·005	11
3	+ ·022	10
6	+ ·028	12
9	+ ·018	8
12	+ ·007	10
15	+ ·005	10
18	+ ·014	7
21	+ ·007	10

Analysing these results on the assumption that each has equal weight, we find—

$\Delta\alpha$ (*Cape Ledgers – Odessa Catalogue*)

$$= +0^s\cdot0123 - 0^s\cdot0023\cos\alpha + 0^s\cdot0080\sin\alpha - 0^s\cdot0100\cos 2\alpha + 0^s\cdot0010\sin 2\alpha.$$

In the formation of the Odessa Catalogue the corrections derived by Nyrén to the tabular positions of the clock stars have not been applied. An analysis of these corrections indicates that to reduce the Odessa Catalogue to an absolute system, the following further corrections are necessary:—

$\Delta\alpha$ (*Odessa Catalogue – Absolute System*)

$$= -0^s\cdot0040\cos\alpha + 0^s\cdot0030\sin\alpha + 0^s\cdot0019\cos 2\alpha - 0^s\cdot0022\sin 2\alpha;$$

whence, through the medium of the Odessa Catalogue, we find—

$\Delta\alpha$ (*Cape Ledgers – Absolute System*)

$$= -0^s\cdot0063\cos\alpha + 0^s\cdot0110\sin\alpha - 0^s\cdot0081\cos 2\alpha - 0^s\cdot0012\sin 2\alpha.$$

A comparison between the Cape Ledgers and the current Greenwich clock star list, based on the discussion in the introduction to the Greenwich Catalogue for 1900, yielded the following results :—

$\Delta\alpha$ (*Cape Ledgers – Greenwich.*)

h	s	No. of Stars.
0	−0·0052	20
3	+ ·0055	24
6	+ ·0113	18
9	+ ·0098	14
12	− ·0026	21
15	− ·0037	20
18	− ·0066	18
21	− ·0016	22

or, in analytical form,

$$\Delta\alpha \text{ (Cape Ledgers – Greenwich)}$$
$$= -0^s{\cdot}0024 \cos\alpha + 0^s{\cdot}0081 \sin\alpha - 0^s{\cdot}0031 \cos 2\alpha - 0^s{\cdot}0014 \sin 2\alpha.$$

It will be noticed that the original corrections to the Cape Ledger system derived from the Cape day observations are confirmed at least in sign (except in the small coefficient of sin 2α) by each comparison, though the amplitudes appear to be somewhat excessive as compared with those indirectly obtained.

My attention has been recently directed to a similar investigation by Thackeray,* which depends in part on more recent Greenwich results than those used above. From this investigation it appears that the proper motions of the standard systems are subject to by no means inconsiderable periodic errors. The comparisons with the Greenwich system have hitherto been made with Newcomb's proper motions, those with Odessa and Pulkovo partly with Auwers' and partly with Newcomb's proper motions. Adopting Thackeray's determinations, the periodic corrections to the centennial proper motions may be expressed as follows :—

Corrections to Newcomb,

$$+0^s{\cdot}015 \cos\alpha - 0^s{\cdot}046 \sin\alpha + 0^s{\cdot}023 \cos 2\alpha - 0^s{\cdot}010 \sin 2\alpha;$$

Corrections to Auwers,

$$+0^s{\cdot}023 \cos\alpha - 0^s{\cdot}049 \sin\alpha + 0^s{\cdot}016 \cos 2\alpha + 0^s{\cdot}0000 \sin 2\alpha.$$

Hence, assuming that the mean epoch for the observations of the Cape Ledgers under discussion is 1910·0, that for the Greenwich observations 1900·0, and those for Pulkovo and Odessa 1906·0 and 1901·0 respectively, the differences *Cape Ledgers – Greenwich*, etc., as already derived, should be further corrected by the following amounts :—

* *Monthly Notices*, lxxi. p. 174.

Cape Ledgers – Greenwich

$$-0^{s}\cdot0015\cos\alpha+0^{s}\cdot0046\sin\alpha-0^{s}\cdot0023\cos 2\alpha+0^{s}\cdot0010\sin 2\alpha,$$

Cape Ledgers – Pulkovo

$$-0^{s}\cdot0005\cos\alpha+0^{s}\cdot0018\sin\alpha-0^{s}\cdot0010\cos 2\alpha+0^{s}\cdot0005\sin 2\alpha,$$

Cape Ledgers – Odessa

$$-0^{s}\cdot0013\cos\alpha+0^{s}\cdot0041\sin\alpha-0^{s}\cdot0021\cos 2\alpha+0^{s}\cdot0010\sin 2\alpha.$$

Applying these corrections and collecting our various results, we derive the following determinations of the periodic corrections to the system of the Cape Ledgers, which closely represents Newcomb's system at the epoch 1910·0 :—

(*a*) From daylight observations at the Cape,

$$+0^{s}\cdot0085\cos\alpha-0^{s}\cdot0148\sin\alpha+0^{s}\cdot0103\cos 2\alpha-0^{s}\cdot0006\sin 2\alpha;$$

(*b*) from comparison with Odessa Time Stars,

$$+0^{s}\cdot0055\cos\alpha-0^{s}\cdot0170\sin\alpha+0^{s}\cdot0064\cos 2\alpha-0^{s}\cdot0014\sin 2\alpha;$$

(*c*) from comparison with Odessa Catalogue Stars,

$$+0^{s}\cdot0076\cos\alpha-0^{s}\cdot0151\sin\alpha+0^{s}\cdot0102\cos 2\alpha+0^{s}\cdot0002\sin 2\alpha;$$

(*d*) from comparison with Pulkovo (Time Stars only),

$$+0^{s}\cdot0043\cos\alpha-0^{s}\cdot0110\sin\alpha+0^{s}\cdot0103\cos 2\alpha+0^{s}\cdot0038\sin 2\alpha;$$

(*e*) from comparison with Greenwich (1900),

$$+0^{s}\cdot0039\cos\alpha-0^{s}\cdot0127\sin\alpha+0^{s}\cdot0054\cos 2\alpha+0^{s}\cdot0004\sin 2\alpha.$$

The investigation leaves no room for doubt that the existing systems of standard stars are subject to by no means inconsiderable systematic errors of a periodic character, and affords a complete confirmation of the results already derived by Thackeray from the later Greenwich observations.

It is probable that the next few years will afford considerable additional evidence, from observations now in progress, which will serve to determine with higher precision the periodic errors affecting the existing standard systems. Adopting, however, provisionally, the mean of the above five determinations as the correction to the Cape Ledger "system," the corresponding corrections to the systems of Newcomb, Boss, and Auwers at the epoch 1910·0 may be expressed by the following formulæ :—

$\Delta\alpha$ (*Newcomb*)

$$=+0^{s}\cdot0058\cos\alpha-0^{s}\cdot0154\sin\alpha+0^{s}\cdot0090\cos 2\alpha+0^{s}\cdot0005\sin 2\alpha;$$

$\Delta\alpha$ (*Boss*)

$$=+0^{s}\cdot0078\cos\alpha-0^{s}\cdot0106\sin\alpha+0^{s}\cdot0096\cos 2\alpha-0^{s}\cdot0022\sin 2\alpha;$$

$\Delta\alpha$ (*Auwers*)

$$=+0^{s}\cdot0077\cos\alpha-0^{s}\cdot0114\sin\alpha+0^{s}\cdot0093\cos 2\alpha+0^{s}\cdot0000\sin 2\alpha.$$

Attention may be directed to the prominence of the secondary period as exhibited throughout this investigation in the coefficient of the term involving cos $2a$. It is most probable that the errors in the standard systems under discussion have been introduced through the medium of some of the earlier catalogues which have dominated throughout the meridian observations on which the existing standard systems are based. This view is at least confirmed by a comparison of the errors here derived with those shown in the diagrams exhibited in the frontispiece of the Greenwich Catalogue for 1890. This diagram vividly illustrates the manner in which the periodic errors in the original system adopted at Greenwich have been gradually reduced by successive approximation. The curves shown not only indicate an error of single period in the initial data adopted for their construction agreeing closely in phase with that now derived, but give unmistakable evidence of a secondary period of proportionate amplitude and concordant phase.

Sun-spots and Terrestrial Magnetic Phenomena, 1898–1911 : *the Greater Magnetic Storms. Second Paper.* By the Rev. A. L. Cortie, S.J.

In a former paper (*M.N.*, *R.A.S.*, lxxiii., p. 52 *et seq.*) the mean seasonal variation in magnetic storms was attributed to the inclination of the Sun's axis to the plane of the ecliptic and the position of the Earth relatively to the sun-spot zones. In the present paper a comparison is instituted between particular magnetic storms and associated sun-spots. The storms selected are the greater magnetic storms which occurred during the period under review. The data are gathered together in the following table, which includes sixteen magnetic storms, any storm which persisted for two days being counted twice.

1. A comparison of the dates of the magnetic storms and the mean heliographic latitude of the sun-spots for the different years shows that the greater number, or eleven of the sixteen, took place not only on the descending arm of the sun-spot curve, but when the sun-spots had attained a mean heliographic latitude about $\pm 10°$. This is consonant with the similar result already noted with regard to all magnetic storms. The maximum sun-spot year 1905 was singularly free of magnetic storms.

2. The columns headed D and H give a measure of the violence of the magnetic storms, in terms of the ranges of the needles in horizontal direction and force. The selection of these greater storms has been made by Father Sidgreaves, who has taken into account not only the absolute ranges but also the character of the

TABLE I.

The Greater Magnetic Storms (1898-1911.)

No.	Date.	Magnetic Range. D.	Magnetic Range. H.	Greenwich. Spot Number.	Greatest Disc-Area. Day.	Greatest Disc-Area. Units.	Heliographic. Longitude. From Central Meridian.	Heliographic. Longitude. Mean of Group.	Heliographic. Latitude. Mean of Group.	Heliographic. Latitude. Earth.	Projected Angular Distance Spot – Earth.
		′	10^{-5} C.G.S.			2×10^{-4}.	°	°	°	°	°
1	1898 Mar. 15	113	727	4702	Mar. 14	8	+53	119·5	−13·2	−7	6
2	Sept. 9	91	723	4781	Sept. 10	20	+ 5	239·0	−12·1	+7	19
3	1903 Oct. 30	94	530	5098	...	...	−18	298·1	−18·8	+4	23
4	,, 31	>165	>742	5098	Oct. 31	6	− 5	...	...	...	...
5	1906 Dec. 22	60	260	6046	Dec. 18	9	+50	321·5	−16·0	−2	14
6	1907 Feb. 9	>165	>742	6108	Feb. 14	22	−44	305·8	−16·6	−7	10
7	Mar. 11	59	125	6140	Mar. 10	7	0	309·5	−16·6	−7	10
8	1908 ,, 26	59	320	6389	,, 28	2	−10	315·2	+11·0	−7	18
9	Sept. 11	>165	>742	6519	Sept. 9	5	+28	279·7	− 5·5	+7	13
10	,, 28	83	247	6533	...	...	+26	45·3	+ 9·2	+7	2
11	,, 29	87	605	6533	Sept. 27	5	+38	..	...	...	...
12	1909 Jan. 3	86	220	6591	Jan. 2	7	− 1	187·1	+ 9·0	−3	12
13	Mar. 19	64	290	6642	Mar. 22	8	−68	207·7	+11·4	−7	18
14	May 14	85	...	6669	...	...	+ 4	266·4	−16·5	−2	15
15	,, 18	41	365	6669	May 13	7	+63	...	...	...	...
16	Sept. 25	>165	>472	6728	Sept. 26	7	+16	306·4	− 4·8	+7	12

disturbance as determining his choice. Four of these storms stand out pre-eminently: those of 1903 October 31; 1907 February 9; 1908 September 11; and, the greatest of all, 1909 September 25. In these four cases the oscillations of the needles were so violent that they exceeded the limits of registration on the photographic films.

3. In the fifth column are given the Greenwich numbers of the sun-spots that accompanied the magnetic storms, and in the two succeeding columns the dates on which these spots attained their greatest area and the values of the areas in terms of $\frac{1}{3000}$ of the visible disc.

From these data it appears that a greater magnetic storm may take place before, or after, or contemporaneous with, the greatest area of the accompanying sun-spots. It is quite true that in many cases there are other sun-spots on the Sun which may possibly assist in precipitating a storm of this class: as, for instance, in the October storm 1903, the February storm 1907, and the March storm 1909, and to a less degree the September storm 1908. But this subject of the relation between total spotted area and magnetic magnitude has been exhaustively discussed by Father Sidgreaves in his paper (*Memoirs R.A.S.*, liv.). On the other hand, the storm of May 1909 and the exceptionally violent one of September 1909 were accompanied by single spots. An interesting case is the storm of 1908 March 26. On March 25 the only groups on the Sun were two small dying spots. On March 26, the date of the violent storm, the Sun was spotless. On March 27 a very small spot appeared west of the central meridian, which did not develop very much, and was very short-lived. Nor were there any recurrent groups to mark the position of this outbreak.

With regard to reappearances of spot-groups, four storms accompanied spots that appeared only once; the other twelve were connected with recurrent groups: four with the first appearance, five with the second appearance, and three with the third appearance. Nor is there any parity between the area of a sun-spot group and the violence of the accompanying magnetic storm, except in the case of the February storm 1907, which, as we have seen, was also concomitant with a large total spotted area. But as a set-off, the monster spot of February 1905, which attained a magnitude of 27 units of area, was unaccompanied by a magnetic disturbance of the first class, the declination ranges on February 2 and 3 being 21′ and 51′, and those of horizontal force 248 and 170 units respectively—a considerable storm, but yet not of such a character is to be admitted into the list of greater storms.

4. It is frequently contended that a sun-spot is in a position of advantage with regard to occasioning a magnetic storm when it is on the central meridian of the Sun's visible hemisphere. There is no warranty at all from observation in support of this view. The column in the table which gives the longitudes from the central meridian of the spots accompanying the magnetic storms shows that the most effective position is entirely independent of

the central meridian. In six cases the spot was within ten degrees of the central meridian; in the other ten it was either east or west, the limiting longitudes being 68° E. to 63° W. The westerly position is the more advantageous, so far as regards the storms contained in the table. This result agrees with that obtained by Father Sidgreaves for all the storms discussed in his paper (*loc. cit.*, p. 94), and with a like result obtained by Mr. Maunder in his paper on the "great" magnetic storms, 1875–1903 (*M.N.*, *R.A.S.*, lxiv. p. 209).

5. The following, in general, are the characteristics of sun-spots which accompany these greater magnetic storms. They are marked by continual change, denoting much internal activity, and by great irregularity of structure. Their umbræ are not, as a rule, continuous, but are made up of a congeries of coalescing fragments. The penumbræ, too, of such spots are darker than in the ordinary spot, very shattered, and shapeless. The Greenwich volumes of sun-spot results give the projected areas of the umbræ of spots and of the whole spots. It has been possible, therefore, to compare the ratio in projected area of the umbræ and whole spots for the spots connected with magnetic storms, and the ratios for the different years in which they occurred, for all the spots recorded in these years. The result is that, for the most part, the ratio of umbral area to total area is greater than the normal in spots connected with magnetic storms. Through the kindness of Dr. Lockyer I have received copies of the spectroheliograms taken at South Kensington on several dates, on or near those on which these greater magnetic storms occurred. Some of the beautiful plates of M. Deslandres' spectroheliographic studies in tome iv. of the *Annales* of the Meudon Observatory also have examples on the dates of these storms, and there is a fine photograph (*Ap. J.*, xxviii. p. 322) of the spots accompanying the storm of the very first magnitude of 1908 September 11, taken in H_α light by Professor Hale on September 7, which shows great right- and left-handed vortices in the flocculi.

In all the cases studied the flocculi were very bright and very compact, in some instances almost completely covering up the underlying sun-spot. Notable among such examples were the flocculi of the spot of 1903 October 31, and of that of 1909 September 25, as portrayed in the plates accompanying Dr. Lockyer's paper (*M.N.*, *R.A.S.*, vol. lxx. p. 14), especially on the day preceding the intense magnetic storm.

6. In the columns which give the mean heliographic co-ordinates of the sun-spot groups it will be noticed that the spots which accompanied all the greater magnetic storms of the years 1903–1907 were practically in the same position, being confined to a belt some 24° in longitude and 3° in latitude. This area on the sun was intermittently active during the whole of the maximum period and was marked by several large recurrent groups. Among them was the greatest group of the whole of this solar cycle, that of February 1905. Besides other magnetic disturbances

five greater storms coincided with the activity of this region—two of them, 1903 October 31 and 1907 February 9, of the very first magnitude. This series of five greater storms formed therefore not isolated but connected phenomena, two of them accompanying successive appearances of the same spot-group 1907 February 9, and March 11. From the Greenwich catalogues of recurrent sun-spot groups we find the following as occupying approximately this region on the Sun during the years 1903–1907. The region began to be disturbed in April 1903 by the appearance of a stream of very small spots.

1903	5021		1905	5704	
	5068			5733	
	5098	Magnetic storms, Oct. 30–31	1906	6046	Magnetic storm, Dec. 22
1904	5154		1907	6076	
	5167			6106	
	5331			6081	
	5356			6108	Magnetic storm, Feb. 9
1905	5416			6140	Magnetic storm, Mar. 11
	5441	Great February spot		6161	
	5471				
	5489				

7. In the average results for all magnetic storms of the classes moderate, great, and very great, presented in the last paper, it was shown that storms are more likely to occur and are more frequent when the spots fall towards the Sun's equator, and the Earth, the maximum heliographic latitude of which does not exceed $\pm 7^\circ$, is placed radially opposite the spot-zones. But in the case of these greater magnetic disturbances—as can be seen from the columns giving the mean latitudes of the groups, the heliographic latitudes of the Earth at the dates of the magnetic storms, and the projected angular distance in heliographic latitude between the spot-groups and the Earth—there are only five cases in which the Earth was heliographically within 10° of the spot-groups, and in the case of the great October storm the difference in heliographic latitude was as much as 23°. Taking Mr. Maunder's list of "great" magnetic storms (*loc. cit.*), we see that the association of spot-groups and great magnetic storm may be effective when the spot is as far north as latitude $+24^\circ{\cdot}5$, and as far south as $-32^\circ{\cdot}0$, the limiting latitudes in the list given above in the table being $+11^\circ{\cdot}4$ and $-18^\circ{\cdot}8$. Accordingly, a monthly curve of greater and great storms alone, excluding the class of moderate storms, which is composed of a very much greater number of storms, would not show the difference between the amplitudes corresponding to the plus and minus values of the maximum heliographic latitude of the Earth, even though spots in the southern hemisphere were more predominant. Such a curve has been drawn and appeared,

for the sake of comparison, below the smoothed curve for storms of all classes in the former paper on the subject (*loc. cit.*, p. 57). These facts also suggest that the mode of propagation of the spot influence from the Sun is not in the form of cylindrical streams of restricted cross section, but of streams which spread as they leave the Sun,—and if the particles composing such streams have like electrical charges, they must necessarily do so, on account of mutual repulsion,—the greater the spot activity which gives rise to them, the greater the density of the streams initially, and the more extensive the spreading as they proceed from the Sun.

8. There is another fact which is opposed to the idea of the cathode ray, or stream-like projection of the influence from the sun-spot regions of activity, which conditions magnetic storms. These storms very frequently occur in batches, the disturbance continuing for four or five days, sometimes longer (*e.g.* 1908 April 22–28, May 21–31). Frequently, too, a sun-spot in its transit across the disc may be accompanied by two or three storms in a batch, and then, after a break, by other isolated storms corresponding to longitudes from the central meridian, widely differing in positive and negative values. The subject of the apportioning of a set of magnetic storms to their proper sun-spots is difficult, and sometimes very elusive when two or three groups of large sun-spots follow one another across the Sun's disc. However, a considerable number of such studies has been made for magnetic storms and different sun-spot groups. A specimen of such tabulations in connection with the violent magnetic storm of 1909 September 25, is given on p. 154. In the Stonyhurst lists of magnetic storms for 1909, there are 35 entries as moderate, 8 as great, and 1 as very great in the period July 1–December 31. The whole of these 44 storms are accounted for by arranging them in 27-day intervals in connection with the two series of recurrent groups 6706, 6722, 6733, 6754, 6772, 6787 as one set, and 6701, 6719, 6728, 6746, 6765 as the other.

Incidentally these studies amply confirm the 27-day period for the recurrence of magnetic storms advocated by Mr. Maunder, as also the intermittent character of the magnetic activity in many cases. But they suggest that either we must suppose that several divergent streams of particles are centred on the same focus of sun-spot activity, or that a series of separate streams are evolved as the spot passes across the Sun, some of the members being almost tangential to the Sun's surface, and sometimes even curving round it in order to reach the Earth, which seems to be impossible.

In conclusion, it would seem that a general state of sun-spot activity corresponds with a general state of terrestrial magnetic activity, but that it requires the advent of a large spot, the influence from which extends in all directions, or a spot favourably situated in heliographic latitude relatively to the Earth, to upset the equilibrium by the precipitation of a magnetic storm. An analogy would be the trigger of a gun at half-cock and at full-cock. If

TABLE II.

Magnetic Disturbance, 1909 *September* 25.

Date	July	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23			I.
Magnetic disturbance . . .													*m*	***m***	*m*									*m*			
Date . . .	July–Aug.	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19			II.
Spot Groups				**6701**	306·5 – 5·0				July 30–Aug. 4.								**6706**	156·3 – 13·8			Aug. 9–16.				
Magnetic disturbance . . .		*m*				*m*	*m*						***m***														
Longitude from C.M. . . .						+26							−33														
Date . . .	Aug.–Sept.	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			III.
Spot Groups				**6719**	292·4 – 5·8			Aug. 29–31.								**6722**	154·3 – 12·4			Sept. 4–14.							
Magnetic disturbance . . .				*m*		*m*	*m*	*m*	*m*			*m*		*m*		*m*	*m*	*m*					*m*				
Longitude from C.M. . . .						+18	+33							−34		−7	+2	+21					+76				
Date . . .	Sept.–Oct.	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12			IV.
Spot Groups				**6728**	306·4 – 4·8			Sept. 17–30.								**6733**	168·4 – 12·6			Sept. 28–Oct. 10.							
Magnetic disturbance . . .			*g*				*v g*				*m*	*g*	*m*	*m*					*m*	*m*							
Longitude from C.M. (1) . .			−21				+19				+71	+84															
(2) . .											−67	−51	−41	−28					+39	+58							
Date	Oct.–Nov.	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8			V.
Spot Groups				**6746**	311·8 – 5·5			Oct. 16–26.								**6754**	167.7 – 14·1			Oct. 25–Nov. 7.							
Magnetic disturbance . . .			*g*	*g*			*m*	*g*	*g*																		
Longitude from C.M. . . .			−34	−21			+19	+32	+51																		
Date . . .	Nov.–Dec.	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5			VI.
Spot Groups				**6765**	311·0 – 4·2			Nov. 12–23.							**6772**	166·8 – 13·4			Nov. 22–Dec. 3.								
Magnetic disturbance . . .			*m*	*m*	*m*			*m*							*m*			*g*	*m*	*m*							
Longitude from C.M. . . .			−40	−26	−11			+41							−25			+17	+32	+44							
Date	Dec.	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31				VII.
Spot Groups															**6787**	172·3 – 12·1			Dec. 19–30.								
Magnetic disturbance . . .					*m*	*g*							*m*										*m*				
Longitude from C.M. . . .													−45										W				

The above list contains the 35 *m*, the 8 *g*, and 1 *v g* magnetic storms recorded at Stonyhurst during the period July–Dec. 1909.

we suppose that the ionisation of the upper atmosphere is a condition for a magnetic storm, then it may well be that the process is a gradual one as spots begin to grow in number and magnitude, until the advent of a specially active or large spot suffices to bring about a great magnetic storm.

Stonyhurst College Observatory :
1913 *January* 4.

Erratum in First Paper, vol. lxxiii., No. 1.
Page 58, line 17, *for* equator *read* ecliptic.

Observations of the Satellite of Neptune, from photographs taken at the Royal Observatory, Greenwich, between 1909 *November* 22 *and* 1910 *April* 15.

(*Communicated by the Astronomer Royal.*)

The following measures of position-angle and distance of Neptune's satellite were made from photographs taken with the 26-inch refractor of the Thompson equatorial. The occulting shutter was used as in previous years. The photographs were taken by Messrs. Davidson, Edney, or Melotte, and were measured in a position micrometer in direct and reversed positions by Messrs. Davidson and Lord. The tabular positions with which comparison is made were computed from data given in the *Connaissance des Temps*, based on Dr. Hermann Struve's elements, the eccentricity of the orbit being neglected. A discussion of these residuals gives the following differences from Dr. Hermann Struve's elements in the sense Tabular – Observed :—

$$du = -1^\circ\cdot08, \quad dN = -0^\circ\cdot92, \quad dI = -0^\circ\cdot32, \quad da = +0''\cdot048,$$

giving for the epoch 1910·2

$$a = 16''\cdot223, \quad N = 189^\circ\cdot06, \quad I = 116^\circ\cdot34,$$

NEPTUNE AND SATELLITE.

Position-angle and Distance from Photographs taken with the 26-inch Refractor.

Date and G.M.T.					Position-angle.			Distance.		
					Obs.	Tab.	T − O.	Obs.	Tab.	T − O.
	d	h	m	s	°	°	°	″	″	″
1909.										
Nov.	22	13	11	20	111·46	112·32	+0·76	16·82	16·58	−0·24
1910.										
Jan.	12	9	57	15	250·06	251·67	+1·61	14·39	14·48	+0·09
	20	12	50	30 (*a*)	102·43	102·88	+0·45	16·92	16·88	−0·04
	20	13	24	46 (*a*)	101·78	101·92	+0·14	16·81	16 87	+0·06
	26	9	5	35 (*b*)	103·22	104·16	(+0·94)	17·51	16·85	(−0·66)
	26	9	37	34	102·30	103·26	+0·96	16·74	16·86	+0·12
Feb.	3	10	40	6 (*c*)	317·92	318·99	+1·07	13·63	13·93	+0·30
	11	10	15	46 (*d*)	205·10	206·53	+1·43	11·30	11·28	−0·02
	15	9	26	13	305·56	308·56	+3·00	15·01	14·98	−0·03
	28	9	56	44	251·37	252·44	+1·07	14·46	14·54	+0·08
Mar.	1	8	14	59	179·15	180·63	+1·48	11·15	11·12	−0·03
	1	8	36	57	177·98	179·27	+1·29	11·11	11·15	+0·04
	1	9	0	0	177·02	177·81	+0·79	11·22	11·19	−0·03
	1	9	20	7	175·88	176·57	+0·69	11·21	11·22	+0·01
	3	9	11	5	70·24	70·84	+0·60	14·38	14·36	−0·02
	3	9	42	30	68·98	69·64	+0·66	14·14	14·23	+0·09
	5	8	37	10	290·97	292·98	+2·01	16·49	16·24	−0·25
	5	9	12	24	290·61	291·95	+1·34	16·17	16·31	+0·14
	5	9	27	21	290·27	291·40	+1·13	16·15	16·34	+0·19
	7	8	4	8	170·63	170·50	−0·13	11·35	11·40	+0·05
	7	8	18	44 (*e*)	168·55	169·63	+1·08	11·39	11·44	+0·05
	7	8	33	46	168·11	168·74	+0·63	11·33	11·48	+0·15
	7	8	50	50	166·79	167·74	+0·95	11·66	11·52	−0·14
	14	7	37	12	105·23	107·04	+1·81	16·22	16·46	+0·24
	14	7	51	13	106·29	106·64	+0·35	16·46	16·48	+0·02
	14	8	5	50	105·14	106·23	+1·09	16·59	16·49	−0·10
	14	8	21	8	104·90	105·79	+0·89	16·37	16·50	+0·13
	16	7	55	1	334·54	336·20	+1·66	12·09	12·13	+0·04
	16	8	19	33	334·06	334·93	+0·87	12·48	12·22	−0·26
	16	8	37	33	333·69	334·01	+0·32	12·23	12·29	+0·06
	16	8	55	11	332·02	333·13	+1·11	12·09	12·36	+0·27
	18	8	58	42	231·93	232·38	+0·45	12·46	12·51	+0·05
	18	9	13	3 (*f*)	230·95	231·67	+0·72	12·17	12·46	+0·29
	18	9	28	45 (*g*)	227·79	230·90	+3·11	12·15	12·40	+0·25
	20	8	46	10	97·94	100·11	+2·17	16·68	16·49	−0·19
	20	9	7	7	98·29	99·52	+1·23	16·49	16·49	0·00
	20	9	23	4	98·45	99·07	+0·62	16·26	16·48	+0·22

NEPTUNE AND SATELLITE—*continued.*

Position-angle and Distance from Photographs—continued.

Date and G.M.T.				Position-angle.			Distance.		
				Obs.	Tab.	T−O.	Obs.	Tab.	T−O.
	d	h	m s	°	°	°	"	"	"
1910.									
Mar.	20	9	37 52 (*f*)	98·33	98·65	+0·32	16·33	16·47	+0·14
	29	8	6 52	272·54	273·70	+1·16	16·39	16·22	−0·17
	29	8	21 45	272·32	273·27	+0·95	16·26	16·20	−0·06
	29	8	38 28	271·59	272·79	+1·20	16·43	16·18	−0·25
	29	8	56 29	272·02	272·27	+0·25	15·95	16·15	+0·20
	31	8	41 1	133·60	134·27	+0·67	13·88	13·98	+0·10
	31	8	56 50	131·94	133·66	+1·72	14·11	14·05	−0·06
	31	9	11 11	132·67	133·11	+0·44	13·76	14·10	+0·34
	31	9	26 26	131·56	132·54	+0·98	14·19	14·16	−0·03
Apr.	1	8	38 53 (*f*)	89·68	90·20	+0·52	15·85	15·99	+0·14
	1	8	52 56	88·36	89·79	+1·43	15·72	15·96	+0·24
	1	9	11 30	87·81	89·24	+1·43	15·68	15·91	+0·23
	1	9	26 8	88·00	88·80	+0·80	15·86	15·89	+0·03
	2	8	19 13	29·51	30·25	+0·74	11·24	11·14	−0·10
	2	8	36 26	27·13	29·20	+2·07	11·02	11·11	+0·09
	2	8	57 39	28·48	27·90	−0·58	10·87	11·07	+0·20
	2	9	12 42 (*f*)	27·20	26·97	−0·23	10·81	11·04	+0·23
	5	8	33 36	202·33	203·89	+1·56	11·04	10·94	−0·10
	5	8	47 53	200·91	203·00	+2·09	10·94	10·92	−0·02
	5	9	3 30	201·17	202·02	+0·85	10·92	10·90	−0·02
	5	9	17 39	200·54	201·12	+0·58	10·75	10·88	+0·13
	15	8	49 30	297·95	298·77	+0·82	15·22	15·43	+0·21

(*a*) Neptune not occulted.
(*b*) Examined.
(*c*) Satellite very faint.
(*d*) Images not round.
(*e*) Neptune very near edge of shutter.
(*f*) Satellite very diffused.
(*g*) Definition very bad.

The satellite of Neptune has now been regularly observed at Greenwich since 1902 with the exception of the opposition 1909. The differences from Dr. Hermann Struve's elements found from the observations are as follows:—

Epoch.	No. of Plates.	*du.*	*dN.*	*dI.*	*da.*	$2e \sin Q$.	$2e \cos Q$.
1902·1	51	−0·95	−0·42	−0·12	+0·087	+·0005	−·0004
1903·1	63	−0·67	−0·40	−0·30	+0·092	+·0005	+·0016
1904·1	51	−0·83	−0·72	−0·20	+0·033	−·0017	+·0002
1905·1	57	−0·82	−0·95	−0·37	+0·069	+·0038	+·0053
1906·1	59	−0·90	−1·17	+0·12	+0·085	−·0043	−·0027
1907·2	29	−1·02	−0·93	−0·20	−0·008	+·0024	+·0009
1908·2	25	−0·64	−0·44	+0·11	+0·244	−·0110	+·0032
1910·2	58	−1·08	−0·92	−0·32	+0·048	−·0039	−·0008

The very small eccentricity has been treated as a quantity to be determined in these solutions; accordingly the figures for *du*, *dN*, *d*I, and *da* differ slightly from those published previously in the *Monthly Notices*, in which the eccentricity is taken as zero.

Royal Observatory, Greenwich:
1913 *January.*

Observations of Occultations of Stars by the Moon, made at the Royal Observatory, Greenwich, in the Year 1912.

(*Communicated by the Astronomer Royal.*)

Day. 1912.		Phenomenon.	Mag.	Telescope.	G.M.T. h m s	Observer.
Jan. 29	Disapp.	W.B. (2) IV 666–7–8	6·8	Sheepshanks	8 16 49·06	A.C.
Apr. 19	,,	W.B. (2) III 902	7·8	Astrographic	7 59 8·51	H.G.
21	,,	B.D. +27°897	9·1	,,	7 45 24·95	W.S.
21	,,	136 Tauri	4·6	,,	7 49 51·52	W.S.
21	,,	W.B. (2) V 1472	9·0	,,	8 4 49·25	W.S.
21	,,	W.B. (2) V 1618	9·1	,,	9 52 51·67	W.S.
21	,,	Piazzi V 279	8·2	,,	10 0 22·73	W.S.
21	,,	W.B. (2) V 1644	7·9	,,	10 5 16·43	W.S.
21	,,	B.D. +27°940	9·0	,,	10 6 45·99	W.S.
21	,,	Piazzi V 287	6·1	,,	10 45 51·25	W.S.
21	,,	,,	,,	Sheepshanks	51·49	G.B.
22	,,	B.D. +27°1286	9·1	Astrographic	8 12 15·95	W.S.
22	,,	B.D. +27°1290	9·1	,,	8 35 30·63	W.S.
22	,,	W.B. (2) VI 1578	8·2	,,	9 9 52·98	W.S.
23	,,	ω^2 Cancri	6·2	Detached Tel.	8 4 45·18	H.F.
23	,,	,,	,,	Sheepshanks	45·07	G.B.
June 20	,,	σ Leonis	4·2	,,	10 44 1·83	G.B.
20	,,	,,	,,	Astrog. Finder	1·63	H.N.
Dec. 17	,,	44 Piscium	6·0	Sheepshanks	6 1 0·24	G.B.

The apertures of the telescopes used are as follows:—

Guiding Telescope of Astrographic Equatorial	10 inches.	Clock—Dent 2014.	
Sheepshanks Equatorial	$6\frac{3}{4}$,,	,,	Earnshaw.
Detached telescope .	4 ,,	,,	Graham I.
Astrographic Finder .	$2\frac{1}{2}$,,	,,	Dent 2014.

The initials A.C., H.F., W.S., H.G., G.B., H.N., are those of Mr. Crommelin, Mr. Furner, Mr. Stevens, Mr. Green, Mr. Bartle, and Mr. Newton.

Micrometrical Measures of Double Stars. By the Rev. T. E. R. Phillips, M.A.

The stars of Struve's *Mensuræ Micrometricæ* in the following list have been measured with the 8-inch Coleman refractor kindly lent by the Council of the Society. The Herschel stars have been measured with the 12½-inch reflector.

The magnitudes of the Struve pairs have been taken from vol. lvi of the Memoirs of the society, and those of the Herschel pairs are the means of estimates by the observer.

In the last column, A = H. F. Acocks, P = T. E. R. Phillips.

Star.	1910. R.A.	1910. Dec.	Mags.	Position Angle.	Dist.	No. of Nts.	Date.	Obs.
Σ	h m	° ′		°	″		1912	
42	0 31·2	+29 30	7·9, 8·7	28·5	5·79	3	·784	P.
60 (η Cassiopeiæ)	0 43·6	57 20	4·0, 7·6	246·7	6·41	3	·771	P.
61 (65 Piscium)	0 45·0	27 13	6·0, 6·0	117·2	4·46	3	·768	P.
73 (36 Androm.)	0 50·8	23 8	6·2, 6·8	37·0	1·09	3	·730	P.
82	0 55·9	9 1	8·3, 9·3	305·5	1·72	3	·772	P.
87	1 10·7	14 58	8·0, 8·5	199·3	6·35	3	·791	P.
				197·5	6·39	2	·809	A.
113	1 15·2	− 0 59	6·2, 7·2	357·1	1·53	3	·735	P.
130	1 27·8	+69 27	8·0, 9·0	186·9	7·56	3	·733	P.
138	1 31·3	7 11	7·3, 7·3	41·9	1·44	3	·739	P.
155	1 39·4	9 0	7·5, 7·9	327·1	4·78	3	·742	P.
174	1 45·1	21 50	6·2, 7·4	166·2	2·76	3	·744	P.
178	1 47·3	10 22	7·8, 7·8	199·7	3·16	3	·750	P.
180 (γ Arietis)	1 48·5	18 51	4·2, 4·4	359·1	8·14	3	·684	P.
				357·9	8·16	4	·694	A.
186	1 51·2	1 24	7·2, 7·2	38·7	0·90	3	·757	P.
194	1 54·2	24 23	8·0, 8·3	268·8	1·12	3	·751	P.
202 (α Piscium)	1 57·4	2 19	2·8, 3·9	314·4	2·86	3	·744	P.
205 (γ Andromedæ A and B)	1 58·4	41 54	2·5, 5·5	63·1	9·91	3	·747	P.
224	2 6·0	13 15	7·5, 8·0	243·4	5·53	3	·757	P.
291	2 36·0	18 25	7·4, 7·7	118·0	3·47	3	·757	P.
305	2 42·4	18 50	7·3, 8·2	315·4	3·32	4	·762	P.
311 (π Arietis)	2 44·2	17 7	4·9, 8·4	117·7	3·36	3	·773	P.
323	2 47·9	6 5	8·0, 8·0	278·6	2·74	3	·795	P.
333 (ε Arietis)	2 54·1	20 58	5·7, 6·0	203·6	1·36	3	·689	P.
				203·9	1·45	3	·705	A.
334	2 54·6	6 17	7·7, 8·2	316·0	1·32	3	·806	P.
376	3 15·3	19 24	7·9, 8·0	251·5	7·00	3	·830	P.
377	3 15·5	18 50	8·3, 8·7	113·9	1·01	3	·830	P.

Star.	1910. R.A.	1910. Dec.	Mags.	Position Angle.	Dist.	No. of Nts.	Date.	Obs.
Σ	h m	° ′		°	″		1912	
381	3 18·1	20 39	7·0, 8·7	98·4	0·99	3	·830	P.
422	3 32·2	0 18	6·0, 8·2	251·6	6·31	3	·730	P.
460	3 54·9	80 28	5·2, 6·1	58·3	0·97	3	·854	P.
470 (32 Eridani)	3 49·8	− 3 13	4·0, 6·0	347·1	6·69	3	·730	P.
491	4 0·9	+10 41	8·2, 8·8	104·0	2·67	3	·826	P.
572	4 32·9	26 46	6·5, 6·5	201·3	3·71	4	·864	P.
652	5 7·1	0 56	6·3, 7·8	181·6	1·74	3	·889	P.
654	5 8·6	2 46	4·8, 8·5	63·0	6·86	3	·932	P.
664	5 10·3	9 1	7·5, 8·0	169·7	4·71	3	·932	P.
665	5 10·4	19 39	8·3, 9·2	251·5	1·41	3	·892	P.
712	5 21·8	2 52	7·0, 9·0	55·0	3·05	3	·929	P.
729	5 26·5	3 13	6·0, 7·3	28·5	2·03	3	·912	P.
730	5 27·0	17 0	6·5, 7·0	140·1	9·74	3	·916	P.
738 (λ Orionis)	5 30·1	9 52	4·0, 6·0	42·9	4·25	3	·912	P.
742	5 31·0	21 56	7·2, 8·2	261·3	3·54	3	·909	P.
2272 (70 Ophiuchi)	18 1·0	2 32	4·5, 6·0	147·3	4·04	3	·457	P.
				148·4	4·01	3	·491	A.
2276	18 1·5	12 0	6·0, 7·0	257·4	6·76	3	·468	P.
				257·9	6·57	3	·492	A.
2289	18 6·1	16 29	6·0, 7·1	229·1	1·19	3	·584	P.
2316 (59 Serpentis)	18 23·2	0 8	5·5, 7·8	317·6	3·94	3	·584	P.
2319	18 23·8	19 14	7·2, 7·7	191·6	5·32	3	·619	P.
2404	18 46·5	10 51	5·8, 7·0	180·3	3·61	3	·473	A.
				182·0	3·54	3	·473	P.
2449	19 2·0	7 0	7·1, 7·8	290·9	7·613	3	·562	A.
2455	19 3·0	22 2	7·2, 8·3	67·4	3·68	3	·478	P.
				68·8	3·72	3	·482	A.
2583 (π Aquilæ)	19 44·4	11 35	6·1, 6·7	111·3	1·52	3	·496	A.
				114·3	1·59	3	·520	P.
2613	19 57·1	10 30	7·0, 7·2	350·4	4·47	3	·527	A.
2621	20 0·2	8 59	7·7, 7·9	223·9	5·72	3	·620	P.
				224·3	5·77	3	·647	A.
2654	20 10·5	− 3 47	6·2, 7·7	235·0	14·07	3	·549	A.
2690 (15 Delphini A and $\frac{BC}{2}$)	20 26·9	+10 57	7·0, 7·5	256·6	15·62	3	·612	A.
2695	20 28·1	25 30	6·8, 8·0	79·4	1·19	3	·584	P.
2698	20 30·0	27 49	8·1, 9·0	304·7	4·55	4	·834	P.
2701	20 32·7	11 44	7·8, 8·2	220·8	2·23	3	·597	P.
2765	21 6·5	9 11	7·8, 8·0	84·0	2·97	3	·593	P.
				84·2	3·19	3	·755	A.

Star.	1910. R.A.	1910. Dec.	Mags.	Position Angle.	Dist.	No. of Nts.	Date.	Obs.
Σ	h m	° ′		°	″		1912	
2799	21 24·5	10 42	8·5, 8·5	291·5	1·52	3	·671	P.
2804	21 28·8	20 19	7·3, 8·0	336·6	3·03	3	·671	P.
				335·7	2·96	3	·671	A.
2878	22 10·0	7 32	6·5, 8·0	125·5	1·29	3	·601	P.
2908	22 23·8	16 48	7·0, 8·7	113·5	9·15	3	·685	P.
				113·6	8·74	3	·701	A.
2909 (ζ Aquarii)	22 24·2	− 0 29	4·0, 4·1	309·7	2·81	5	·624	P.
				307·9	3·16	3	·699	A.
3000	23 14·3	+24 43	8·7, 8·8	52·6	3·34	3	·710	P.
3012	23 23·0	16 8	8·7, 8·8	189·4	2·95	3	·712	P.
3013	23 23·1	16 8	7·8, 9·3	272·2	2·82	3	·712	P.
3014	23 23·4	10 38	8·1, 10·4	278·7	8·22	3	·678	P.
				278·5	8·01	3	·694	A.
3019	23 26·1	4 45	7·1, 8·1	185·4	10·73	3	·719	P.
3041	23 43·2	16 34	7·3, 8·1	178·6	3·25	3	·721	P.
3050	23 54·6	33 13	6·0, 6·0	221·1	2·19	3	·727	P.
3061	0 1·1	17 20	8·0, 8·0	146·8	7·66	3	·733	P.
				147·5	7·34	2	·756	A.
h								
1313	18 2·8	28 42	9, 11·5	307·9	15·16	4	·416	P.
1315	18 6·4	29 39	10·5, 12·3	130·5	9·01	3	·352	P.
1317	18 13·5	27 21	9·8, 11·3	129·1	18·19	4	·432	P.
1318	18 15·6	28 6	10·6, 11·1	138·1	11·54	4	·360	P.
1322	18 19·5	27 44	9·5, 10·2	242·3	20·14	5	·635	P.
1324	18 23·0	28 38	9·5, 10·5	14·9	6·35	4	·437	P.
1343	18 42·3	27 13	9·8, 11·5	117·5	7·86	5	·513	P.
1343 (Star 1″·3 *sf*)			11, 11·5	129·2	13·57	3	·455	P.
1355	18 50·5	27 11	10, 10·5	33·7	13·24	4	·758	P.
1388	19 18·0	30 0	8·6, 11·0	212·9	20·81	3	·773	P.
1450	19 50·0	30 2	10·5, 10·5	251·1	9·45	5	·794	P.

Notes.

Σ 2722. Now widening rapidly.

Σ 2909. Angle diminishing much more rapidly than formerly. About 10° in last 10 years.

h 1313. Angle about 14° less than that given by *h*.

h 1318. *h* makes magnitudes of stars equal.

h 1322. *h* makes 2 magnitudes difference between stars.

h 1355. Angle about 19° greater than that given by *h*.

The places of the Herschel pairs in the above list are those given by *h* corrected for precession, but the identifications in some instances appear doubtful.

New Double Stars. By Rev. T. E. Espin, M.A.

No.	B.D.	R.A. 1900.	Decl.	P.	D.	Mags.		Nights.	Date. 1912.	
		h m	° ′	°	″					
1126	+47° 12	0 4·3	+47 25	320·4	6·12	9·0	9·7	3	·918	
1127	+47° 18	5·8	47 47	298·6	1·98	10·0	10·7	3	·945	BC
				0·9	89·32	A=	9·2	3	·945	AB
1128	+49° 98	23·3	50 7	172·7	4·17	9·5	11·7	2	·832	
1129	+48° 152	25·4	48 44	84·7	1·45	9·3	9·4	3	·987	
1130	+49° 342	1 11·4	49 27	361·7	3·20	9·3	11·6	3	·796	
1131	+48° 458	26·4	49 0	317·8	3·57	9·5	10·2	3	·918	
1132	+48° 495	33·1	48 30	182·4	5·95	9·3	11·7	2	·898	
1133	+49° 725	2 31·6	49 49	293·3	3·26	9·3	10·3	4	·221	
1134	+49° 751	36·2	49 38	362·3	4·83	9·0	11·7	3	·292	
1135	+49° 768	43·8	48 39	40·2	4·22	9·5	9·7	2	·809	
1136	+48° 923	3 21·4	48 36	9·6	6·68	9·3	11·6	3	·066	
1137	+49° 1038	43·8	49 22	75·9	1·18	9·5	9·8	4	·111	
1138	+49° 1279	4 50·4	49 19	339·9	5·60	9·5	9·6	3	·077	
1139	+49° 1284	52·7	49 21	109·4	2·00	9·2	9·4	4	·130	AB
				343·1	7·75	C=	13·5	3	·117	AC
1140	+48° 1259	5 15·1	48 16	286·7	2·87	9·4	10·3	2	·167	
1141	+48° 1290	29·6	48 10	267·9	3·39	9·1	9·6	3	·182	
1142	+49° 1567	6 47·1	49 52	278·7	3·01	9·5	12·0	2	·174	
1143	+48° 1553	7 29·9	48 16	277·9	4·55	9·0	12·0	2	·194	
1144	+46° 1356	8 0·9	46 29	337·8	7·63	9·0	9·2	3	·244	
1145	+46° 1358	1·9	46 15	77·7	6·38	9·5	10·2	3	·277	AB
				245·3	14·15	C=	13·5	2	·272	AC
1146	+46° 1447	44·6	46 32	165·6	6·22	9·4	11·9	3	·252	
1147	+45° 1682	9 1·4	45 35	179·5	7·20	8·9	9·0	2	·254	AB
				272·3	31·70	C=	10·2	2	·254	AC
1148	+45° 1702	12·3	45 4	31·0	6·03	8·8	9·6	4	·261	
1149	+47° 1740	58·7	47 3	249·8	7·92	8·6	12·0	3	·261	
1150	+46° 1634	10 24·2	46 3	306·5	2·74	9·3	10·8	4	·277	
1151	+44° 1992	24·8	44 45	301·2	2·80	9·5	9·6	3	·287	
1152	+45° 1845	31·0	45 35	348·5	3·57	9·3	9·4	2	·267	
1153	+44° 2112	11 33·2	44 39	263·1	5·42	8·9	11·5	3	·315	
1154	+44° 2142	48·2	43 50	337·2	3·23	9·6	9·9	3	·314	
1155	+45° 2029	12 18·9	45 14	194·8	3·93	9·8	10·7	3	·296	
1156	+45° 2152	14 0·7	45 37	264·9	2·48	9·6	9·6	3	·337	
1157	+46° 2428	18 4·2	46 46	16·2	4·47	9·8	10·5	3	·796	BC
				180·8	25·93	A=	7·8	3	·796	AB
1158	+47° 2612	16·6	47 21	198·1	4·92	8·0	11·5	3	·796	
1159	+46° 2521	35·8	46 55	254·0	3·57	9·1	10·8	3	·809	AB
				336·1	18·87	C=	10·3	2	·800	AC
1160	+46° 2522	36·1	46 53	1·9	1·86	9·5	11·5	5	·819	
1161	+47° 2688	42·7	47 40	269·5	3·72	9·2	9·4	2	·717	
1162		19 9·5	47 2	91·0	2·37	9·6	10·5	3	·777	

No.	B.D.	R.A. 1900. h	m	Decl. °	′	P. °	D. ″	Mags.		Nights.	Date. 1912.	
1163		19	20·6	47	26	119·6	2·46	9·6	11·2	2	·790	AB
						190±	8±	C=	14·0	2	·790	AC
						233·1	26·30	D=	10·0	2	·790	AD
1164	+46° 2718		29·9	46	48	281·2	4·67	9·3	12·5	3	·860	
1165	+47° 2884		35·9	47	55	297·2	4·52	9·6	9·7	2	·772	
1166		20	56·3	46	35	115·8	1·75	9·3	9·7	3	·703	
1167	+46° 3150		58·8	46	17	228·2	5·00	8·6	12·1	3	·720	AB
						78·9	16·30	C=	13·2	3	·720	AC
1168	+45° 3391	21	1·7	45	16	114·7	1·62	9·4	10·2	4	·879	
1169	+46° 3185		3·3	46	44	84·9	5·67	9·4	12·5	3	·743	
1170	+45° 3537		22·6	45	57	344·7	5·41	9·0	12·7	4	·852	AB
						346·1	10·79	C=	13·2	4	·852	AC
1171	+46° 3324		24·6	46	47	193·8	3·63	9·4	9·5	3	·769	AB
						228·5	20·72	C=	12·5	3	·769	AC
1172	+46° 3368		30·7	46	59	106·1	6·62	9·0	9·5	3	·849	AB
						208·6	16·23	C=	9·8	3	·849	AC
1173	+46° 3373		31·3	46	56	94·3	3·48	9·3	10·5	3	·849	
1174	+47° 3488		32·4	47	47	253·5	2·13	9·3	9·8	3	·649	
1175	+49° 3650		48·9	49	45	195·4	4·00	9·4	10·8	2	·757	
1176	+47° 3638		55·0	47	19	270·1	5·75	10·5	12·3	3	·973	BC
						142·3	32·43	A=	8·8	3	·973	AB
1177	+47° 3691	22	1·8	47	17	302·2	6·00	9·5	11·9	2	·961	
1178	+48° 2638		7·8	49	11	117·5	1·74	9·5	9·7	4	·852	
1179	+50° 3658		14·8	50	52	101·4	6·05	9·0	12·8	3	·701	
1180	*h*1766		22·6	49	48	272·4	4·15	9·1	13·2	2	·764	BC
						266·0	13·57	C=	9·6	2	·764	AB
1181	+48° 3753		27·0	48	42	115·2	1·75	9·3	9·6	2	·931	
1182			27·4	48	45	250·1	1·97	9·5	10·3	2	·931	
1183	+49° 3992		52·1	49	31	272·3	5·35	9·5	10·8	3	·771	
1184			53·7	50	34	245·2	1·51	9·6	9·7	4	·526	
1185	+49° 4010		58·1	49	15	318·0	4·15	9·5	10·8	3	·781	
1186	+47° 4090	23	11·5	47	28	89·6	4·03	9·3	12·3	3	·940	
1187	+50° 4033		19·3	50	52	135·6	3·38	9·5	12·5	4	·745	AB
						333·2	6·65	C=	13·8	3	·741	AC
1188	+49° 4109		19·6	49	44	144·5	3·17	9·5	10·7	2	·896	
1189	+49° 4126		22·7	50	5	138·7	1·75	9·4	9·7	2	·791	
1190	+50° 4136		39·3	50	58	106·7	5·72	9·5	10·7	3	·771	
1191	+48° 4232		58·3	48	20	14·1	3·82	9·4	12·8	3	·823	

Notes.

1130. There is a *comes* mag. 13·5 P 97°·6 D 11″·6.

1137. Professor Fox has kindly measured this star,

1912·099 P 78°·7 D 1″·24 Mags. 10·2, 10·3; 4 nts.

1163. The *comes* C is too faint to measure.

1180. The *comes* to B was missed in my earlier observations of this star.

Observations of R Cygni when near the Minimum.
By the Rev. T. E. Espin, M.A.

A careful watch has been kept upon R Cygni during the minimum, with the hopes of seeing the nebulous appearance which Mr. Grover has observed. Mr. Hilger made for me a small spectroscope of low dispersion, which readily showed the nebula spectrum of the Nova Lacertæ when it was of the 12th magnitude. Some difficulty was at first encountered through the lack of a chart of the small stars near R Cygni. Two small stars are given in *H.A.*, vol. xxxvii. part 2, p. 188, as near the variable with the following positions:

α	$\Delta\alpha$	−3 sec.	$\Delta\delta$ +0″·5	Mag. 13·93
β		0	−0·3	14·42

In the earlier observations a star was observed which was considered to be β till a measure on September 21 with the micrometer gave me from B.D+49° 3065,

P 193°·9, D 90″·4;

and a letter from Mr. C. L. Brook, to whom I had written under the impression that the variable was invisible, showed me that the error lay in the position of β. There is no glimpse of any such star in the 17¼-inch. It has been frequently looked for this autumn, but never suspected. There is, however, a faint star, *fs*, estimated 15 mag. Professor Barnard has kindly measured this with the 40-inch at the Yerkes Observatory:

1912 Oct. 15 P 108°·4 D 14″·63 Mag. 15.

On the nights of September 16 and September 21 measurements were made of the angles and positions of all the faint stars near R Cygni. From these the accompanying chart has been laid down. The following estimates were made of the brightness of these stars:

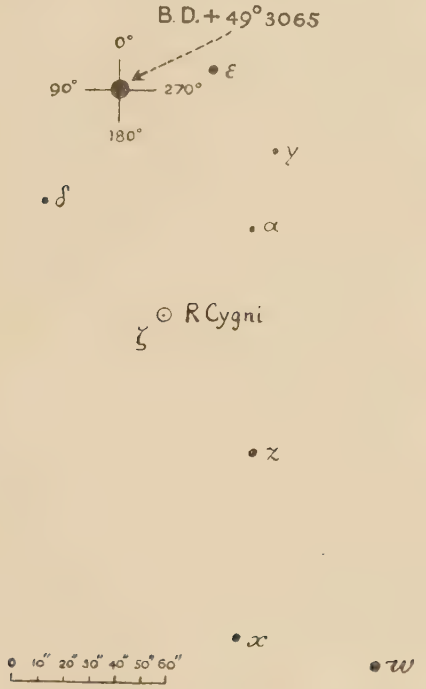
α	13·9
γ	14·3
δ	13·7
ϵ	14·4
ζ	15·0

The comparison star Z being taken as 13·5.

The following are the estimates of magnitude of R Cygni:

1912 Sept. 2	14·0	Oct. 14	13·7
6	14·0	17	13·6
11	13·8	22	13·4
14	13·8	29	13·2
16	13·8	30	13·1
27	13·8	Nov. 1	13·0
Oct. 3	13·8	10	12·6
8	13·7	18	12·5
10	13·7	29	12·0

The star has been examined with high powers on good nights, but was always sharply defined, and no nebulosity suspected. On October 22 the star was hazy-looking, but the definition was not good. Bringing the spectrum to a line on the finest nights in October, it was plain that it was not a nebula spectrum. On November 1 in fair definition the spectrum was obviously discontinuous, and the great band at D was seen. On November 29,



the star having brightened, the spectrum was better seen. In the yellow and green appeared two bright spaces, which were probably bright lines.

Rejecting the observations of September 2 and 6, which were simple estimates, it seems probable that the star's light remained constant during September, and only began to brighten after the first week in October.

The observations during this minimum have failed to show any nebulous appearance in R Cygni.

On the short period variable SU Draconis. By C. Martin and H. C. Plummer. (Plate 8.)

1. This star (B.D. $+68°{\cdot}652$) was found to be variable by Miss Leavitt * in 1907 from an examination of plates of the Harvard map of the sky, and received the provisional number 43·1907. Its position is (*A.G.C.*, Christiania, 1788)

$$1900.0: \quad 11^h\ 32^m\ 15^s{\cdot}15, \quad +67°\ 53'\ 10''{\cdot}2.$$

The star was observed photographically with the 15-inch reflector of the Dunsink Observatory in the autumn of 1912, and 67 measurable exposures were obtained between October 7 and December 16. The whole of the observations and reductions were made by Mr. Martin, who selected the star in order to test the reality of certain secondary fluctuations which he had encountered in the course of his work, and which are often overlooked or misunderstood when methods of an inferior order of accuracy are employed.

2. As the method which has been evolved at this observatory for obtaining differential estimates of stellar magnitude would appear to give very accurate results, it is important that this method should be clearly understood. The exposures given are comparatively long—much longer than is necessary merely to produce an image. Under normal circumstances about half an hour is given for a star of the ninth magnitude. In this time a fairly large and dense image is obtained. In this there is a resemblance to the extra-focal method of Schwarzschild, although in this case the enlargement is merely due to optical properties of the mirror, which, in other circumstances, would be considered a serious imperfection. Instead of measuring the density of the image with a photometer, its diameter is measured with a micrometer. In this process lies the point of chief importance. Those who are most familiar with the nature of the images formed by a reflector would naturally be the least hopeful of a successful result by such a method. Nor is it very readily obtained. The whole image is not of uniform density, and when the extreme outer edge is taken for the settings no consistent measures of magnitude can be made, unless perhaps the quality of the image is exceptionally favourable. But within the image is a denser nucleus, and it is on the edge of this that the settings must be made. This edge is marked by no conspicuous degree of contrast, and consequently the success of the method depends very largely on a kind of specialised personal skill acquired by practical experience. Experience also teaches that the illumination of the plate in the micrometer requires special attention.

3. The formula connecting photographic magnitude (m) and measured diameter (D), which has been found to suit the Dunsink plates best, is †

$$m = a - b\mathrm{D}^{2/3}.$$

* *Harvard Circ.*, 127; *A.N.*, 4181. † *M.N.*, lxxi. p. 511.

A set of comparison stars whose magnitudes are known would determine the constants a and b of this formula, and the magnitude of the variable could then be calculated. In practice this is done by a purely graphical method. The comparison stars give a set of points which are plotted on squared paper by means of their rectangular co-ordinates ($D^{2/3}$, m). Through these the best straight line is drawn. Then if the line $x = D^{2/3}$ is also drawn, D being the measured diameter of the variable, the ordinate of the point of intersection of the two lines gives the magnitude of the variable. This method is found to give satisfactory results and is very rapid.

4. The method employed to determine the photographic magnitudes of the comparison stars, in the choice of which great care is taken to get a symmetrical distribution about the variable, is to photograph both the region and the χ Persei cluster on the same plate, under the same conditions as far as possible in respect to altitude and exposure. For the χ Persei stars we have the determinations of Schwarzschild,* which give the required means of finding the magnitude scale for the plate. In the present case two such plates were exposed and the measures give the following results :—

TABLE I.

Star.	Plate 1015. m_1	Plate 1020. m_2	Diff. $m_2 - m_1$	Adopted Ph. mag.
B.D. +67°·703	9·36	9·48	+0·12	9·42
B.D. +68°·659	9·97	10·08	+0·11	10·02
B.D. +68°·648	10·01	10·15	+0·14	10·08
B.D. +68°·655	10·29	10·40	+0·11	10·34
B.D. +67°·716	10·55	10·68	+0·13	10·61

These results illustrate well the weak and the strong points of the method on which we have to rely for the magnitudes of the comparison stars. In its favour is the constancy of the systematic difference, which is sufficient to satisfy the requirements of *differential* measures of the variable magnitude. On the other hand, the discordance between the two plates leaves an uncertainty in the absolute magnitudes which could only be diminished by multiplying the number of plates with exposures on the standard region. In spite of the care taken to secure equal effective exposures on the two different regions, there may well be local inequalities in the transparency of the sky, which will account for the difference of $0^m{\cdot}12$ between the two plates, and there may be an effect of the nature of "driving error," due to the unequal declination of the two regions.† Even if the mean error were reduced by multiplying the determinations of the comparison star magnitudes, a systematic error might still exist, depending on the relative positions of the variable and of the comparison stars on the plate, which is $3\frac{1}{4}$ in. square in area and covers one and a half

* *Publ. der v. Kuffner'schen Sternwarte*, v. (1900), C.

† There is also a possible systematic error depending on the mere order of two exposures on one plate. *Cf. Astrophysical Journ.*, xxxvi. p. 374 (footnote).

square degrees. On the whole, it seems wise to rest content with the differential character of the work, and to admit frankly the absence of an absolute standard in the magnitudes.

5. Table II. contains the details of the observations. The first column gives the date and G.M.T. of the middle of the exposure. The next column gives the corresponding Julian date and decimal fraction of a day from G.M. noon. By the phase in the third column is meant the decimal fraction of a day which has elapsed since the epoch, the epoch chosen being the time in each period corresponding to the time of the first exposure in November (Nov. 1 : 6^h37^m). This may be taken as very approximately the time of maximum. The time of exposure will be found in the fourth column ; this has been determined chiefly by the atmospheric conditions. The next column gives the concluded photographic magnitudes. The nature of the curve with which the observed values are compared in the sixth column will be explained in § 9. The final column gives the observer's estimate of the quality of the images, formed in the course of measuring the plates.

TABLE II.

Date G.M.T. 1912.			Julian Day. 2419	Phase in days.	Exposure. min.	Mag.	Obs. − Curve.	Images.
Oct.	7	10 53	683·454	·274	30	10·05	+ ·04	Bad.
	9	8 13	685·342	·181	35	9·85	+ ·01	Good.
	9	8 49	685·367	·206	35	9·93	+ ·06	Good.
	9	11 37	685·484	·323	35	10·15	+ ·05	Fair.
	9	12 12	685·508	·347	35	10·35	− ·02	Bad.
	10	8 54	686·371	·549	35	10·24	+ ·06	Fair.
	10	9 30	686·396	·574	35	9·95	+ ·03	Bad.
	14	7 52	690·328	·544	35	10·31	+ ·03	Good.
	14	8 28	690·353	·569	35	10·02	+ ·02	Good.
	14	10 55	690·455	·011	35	9·36	+ ·03	Fair.
	18	10 46	694·449	·042	35	9·70	− ·01	Good.
	18	11 22	694·473	·066	35	9·74	− ·01	Good.
	31	6 37	707·276	·321	45	10·25	− ·05	Fair.
	31	8 25	707·351	·396	45	10·21	− ·01	Good.
Nov.	1	6 37	708·276	·000	45	9·37	− ·01	Good.
	1	8 21	708·347	·071	45	9·73	·00	Good.
	1	10 2	708·418	·142	45	9·96	+ ·06	Good.
	7	6 38	714·277	·057	35	9·69	+ ·06	Good.
	7	7 15	714·302	·082	35	9·70	+ ·05	Good.
	7	8 42	714·363	·143	35	9·99	+ ·03	Good.
	11	7 3	718·294	·112	35	9·95	+ ·01	Good.
	11	9 30	718·396	·214	35	10·04	·00	Bad.
	11	10 6	718·424	·242	35	10·18	·00	Bad.
	11	10 42	718·447	·265	35	10·12	+ ·02	Bad.
	11	12 49	718·534	·352	39	10·32	+ ·02	Fair.

TABLE II.—*continued.*

Date G.M.T.			Julian Day.	Phase (in days).	Exposure.	Mag.	Obs. − Curve.	Images.
1912.	h	m	2419		min.			
Nov. 11	13	27	718·561	·379	35	10·25	·00	Fair.
11	16	30	718·688	·506	35	10·42	+ ·03	Good.
11	17	5	718·712	·530	35	10·37	+ ·02	Good.
12	6	16	719·261	·418	35	10·16	·00	Fair.
12	6	49	719·284	·441	30	10·22	+ ·02	Fair.
13	6	21	720·264	·100	40	9·82	+ ·03	Fair.
13	7	2	720·293	·129	40	10·02	+ ·03	Fair.
13	10	14	720·427	·263	33	10·10	+ ·04	Good.
13	12	21	720·514	·350	35	10·36	− ·02	Good.
13	12	56	720·539	·375	35	10·26	+ ·02	Good.
30	6	25	737·268	·593	40	9·79	− ·02	Good.
30	7	6	737·296	·621	40	9·50	+ ·02	Good.
30	7	54	737·330	·655	40	9·39	− ·04	Good.
30	8	36	737·358	·023	40	9·54	·00	Good.
30	11	2	737·459	·124	35	10·02	+ ·01	Good.
Dec. 2	5	59	739·249	·593	40	9·75	+ ·02	Good.
2	6	40	739·278	·622	40	9·46	+ ·04	Good.
2	8	28	739·353	·037	21	9·65	·00	Good.
2	10	5	739·421	·105	35	9·89	·00	Good.
2	11	17	739·470	·154	27	9·91	+ ·04	Good.
2	12	14	739·510	·194	35	9·93	− ·02	Good.
6	6	1	743·251	·632	40	9·44	·00	Fair.
6	6	39	743·278	·659	36	9·40	− ·05	Fair.
6	9	6	743·379	·100	35	9·89	− ·03	Good.
6	9	42	743·405	·126	35	10·08	− ·04	Good.
8	12	25	745·518	·258	37	10·10	+ ·07	Good.
9	10	40	746·445	·524	35	10·43	− ·02	Good.
9	11	15	746·468	·547	35	10·34	− ·02	Good.
9	11	53	746·495	·574	35	10·09	− ·10	Good.
9	12	38	746·527	·606	35	9·70	− ·05	Good.
11	11	39	748·486	·584	35	9·90	− ·02	Good.
11	12	31	748·521	·619	35	9·58	− ·04	Good.
12	11	42	749·488	·265	35	10·15	− ·02	Good.
12	12	10	749·507	·284	15	10·08	− ·02	Bad.
16	11	7	753·462	·276	35	10·11	− ·02	Good.
16	11	46	753·490	·304	35	10·12	− ·02	Fair.
16	12	41	753·529	·343	35	10·31	+ ·02	Good.
16	13	19	753·556	·370	35	10·29	+ ·03	Good.
16	13	59	753·583	·397	35	10·20	− ·01	Fair.
16	14	35	753·608	·422	35	10·19	− ·02	Fair.
16	15	24	753·642	·456	35	10·34	·00	Good.
16	15	59	753·666	·480	35	10·45	− ·02	Good.

6. The period to which the observations have been referred was determined thus. The following preliminary elements have been given by Seares * :—

$$\text{Max.} = \text{J.D. } 2418073{\cdot}70 + 0^{d}{\cdot}6604\,E, \qquad \text{G.M.T.}$$

Now the epoch of maximum first suggested by the Dunsink observations is J.D. 2419708·276, although it appears subsequently that this may be about $0^{d}{\cdot}01$ too late. Assuming that 2475 periods have elapsed in the interval, we obtain for the elements

$$\text{Max.} = \text{J.D. } 2419708{\cdot}276 + 0^{d}{\cdot}6604\,347\,E, \qquad \text{G.M.T.},$$

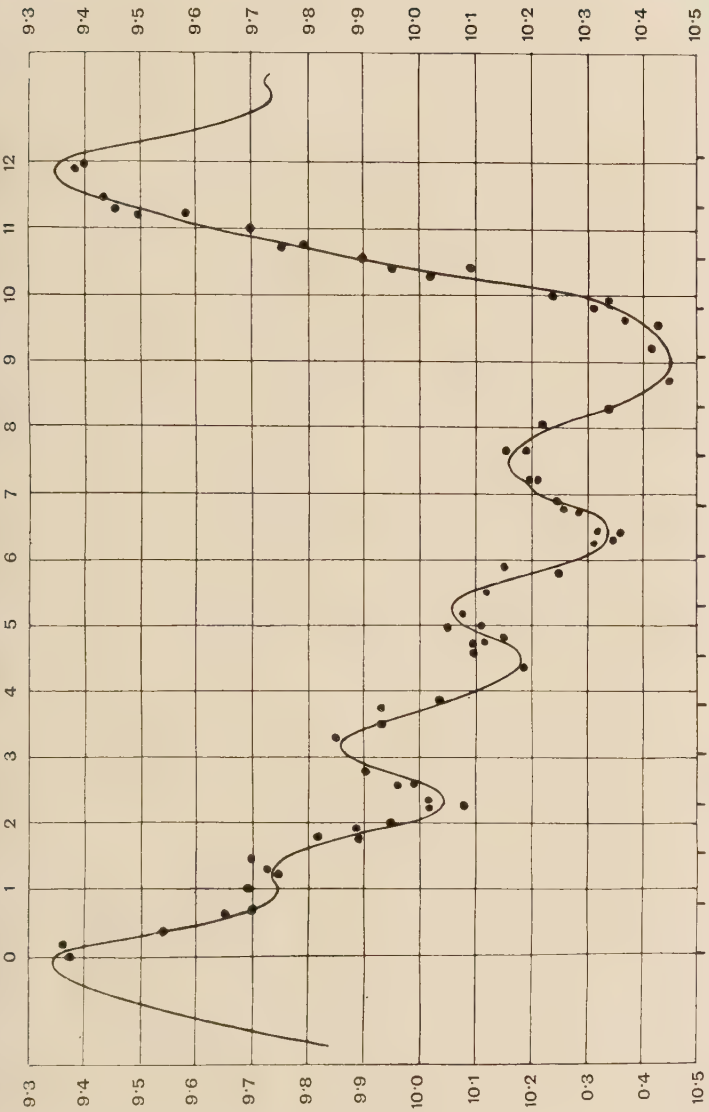
and this period has been adopted. There is no doubt that it is satisfactory for the short time covered by the present observations. If the later epoch of maximum were antedated as suggested, the period would be more nearly $0^{d}{\cdot}6604\,30$, but any such estimate is subject to the assumption that the epochs of visual and photographic maximum are identical, and this is far from being necessarily true. For this reason we cannot infer with any certainty by comparison with Sperra's † period, $0^{d}{\cdot}660419$, based on his own visual observations between 1908 June and 1909 September, that the period is lengthening, although this is quite possible. It should be mentioned that the refinement of the reduction to heliocentric time has been dispensed with in the present observations. It is easily understood that the period found by Enebo, ‡ $0^{d}{\cdot}3978$, which is certainly spurious, is based on a wrong interpretation of the "anomale Maxima" to which he refers.

7. The observed magnitudes were plotted according to the adopted period, and a smooth curve was drawn through them, following the remarkable sinuosities which they clearly exhibited. A marked secondary variation in one-sixth of the period was so plainly suggested that a preliminary attempt was made to determine it separately. But the direct attempt revealed no considerable amplitude with this sub-period. The ordinary method of periodic analysis was then followed, based on 24 ordinates read off at equal distances over the period. The result of the analysis, which was facilitated by the use of a very convenient form of calculation devised by Professor Whittaker, is given in full :—

$$\begin{aligned} m = 10{\cdot}02 &+ {\cdot}34 \sin(\theta + 239^{\circ}{\cdot}9) + {\cdot}19 \sin(2\theta + 271^{\circ}{\cdot}9) + {\cdot}15 \sin(3\theta + 301^{\circ}{\cdot}6) \\ &+ {\cdot}05 \sin(4\theta + 345^{\circ}{\cdot}4) + {\cdot}03 \sin(5\theta + 166^{\circ}{\cdot}0) + {\cdot}06 \sin(6\theta + 11^{\circ}{\cdot}7) \\ &+ {\cdot}03 \sin(7\theta + 267^{\circ}{\cdot}8) + {\cdot}02 \sin(8\theta + 244^{\circ}{\cdot}0) + {\cdot}02 \sin(9\theta + 236^{\circ}{\cdot}8) \\ &+ {\cdot}01 \sin(10\theta + 236^{\circ}{\cdot}7) + {\cdot}01 \sin(11\theta + 146^{\circ}{\cdot}0) \end{aligned}$$

where the origin of θ corresponds with the epoch mentioned above, and the period 2π with the period of the star. The slow and rather irregular convergence of the series is very noticeable. This is unfortunate for two reasons. In the first place, the proper representation of the observations by harmonic components evidently demands a large number of constants. In the second place, it is difficult to know how many terms are required in order

* *Laws Obs. Bull.*, No. 15. † *A.N.*, 4407. ‡ *A.N.*, 4223.



Photographic Light Curve of SU Draconis.

to give due weight to the observations without merely reproducing their accidental errors. In a former paper published by this Observatory,* on the variable RW Cassiopeiæ, the first six terms only were retained. A glance at the curve accompanying the paper is enough to show that these are insufficient to represent the observations adequately.

8. It might be thought that the terms with amplitude no greater than $0^m{\cdot}03$ might be safely neglected. As a matter of fact —and this is a most interesting point—they are the very essence of the harmonic representation of the most important feature of the curve. In order to see this clearly we have only to combine the fifth and seventh components and compare with the sixth thus:

$$+0{\cdot}06 \sin (6\theta + 11^\circ{\cdot}7) - 0{\cdot}06 \sin (6\theta + 36^\circ{\cdot}9) \cos (\theta + 50^\circ{\cdot}9).$$

The second factor of the second term varies slowly through the whole period, so that at one point ($\theta = 129^\circ{\cdot}1$) the two variations are nearly in the same phase and combine to produce an amplitude of nearly $0^m{\cdot}12$ in one-sixth of the whole period, while at another point ($\theta = 309^\circ{\cdot}1$) the two variations are in opposite phase and nearly destroy one another. Thus the most remarkable feature of the light curve, the marked oscillations on the descending branch, is represented by the analysis as an effect having some analogy to group velocity in the theory of wave motion. Otherwise the smallness of the coefficients in the periodic series presents nothing unusual, and rather suggests that this star does not differ essentially from other variable stars whose light curves appear to the eye more regular. The only difference is that in this case the phases of the minor components happen to be more favourable to the production of a very striking effect.

9. The curve which is shown in the accompanying plate (Plate 8) is based on the complete series, as given in § 7, with the exception of the terms depending on 10θ and 11θ. The two preceding terms have little effect of importance on the curve except in the neighbourhood of the maximum, but here their neglect would involve a systematic divergence from the observations on the ascending branch. The large number of terms employed may leave a doubt whether we have not conceded too much to the observed magnitudes, the more so as the curve has no physical foundation which would impose conditions on its form, and it is not very easy to assess the accuracy of the observations *a priori*. However this may be, the discordances have been read from the curve, and are given in the sixth column of Table II. Their average value is $\pm 0^m{\cdot}026$. The formula contains 19 constants, and there are 67 observations. Without balancing probabilities too nicely, it seems likely that the probable error of a magnitude determined from a single plate (in the differential sense, always understood) is less than $0^m{\cdot}03$, or, at all events, not much greater

* *M.N.*, lxxi. p. 511.

than this. The best test of this figure will probably be gained practically by prosecuting the work now in hand on similar stars. A rough idea of the accuracy aimed at will be gathered by noticing that the fluctuations in the curve as the minimum is approached are of something like the same order as the variation in the magnitude (photographic) of Polaris.

10. The comparison of the photographic results with the results obtained by visual observers is interesting. We have seen how the secondary maxima led astray the first attempt to find the period. In his preliminary announcement (*loc. cit.*) Seares says: "The variation approaches closely the Antalgol type. Three hours are required for the ascent from minimum to maximum. Seven hours after maximum the star is within a few hundredths of a magnitude of minimum brightness, the variation during the remaining 5^h50^m of the period amounting, at most, to $0^m{\cdot}06$ or $0^m{\cdot}08$. The range shown by the observations is $0^m{\cdot}7$." Enebo (*loc. cit.*) gives the same range, and remarks: "Anscheinend verweilt jedoch das Licht von 43·1907 Draconis etwa zwei Stunden im Minimum, was jedoch durch visuelle Schätzungen, wegen des Mangels guter Vergleichsterne, schwierig sicher konstatiert werden kann." The most prolonged and complete study of the star is that made by Sperra (*loc. cit.*). The range found by him is $0^m{\cdot}67$, confirming the other visual estimates. Some sentences from his paper may be quoted: "The maximum phase of this star is quite flat, remaining near greatest light for nearly two hours, followed by a very slow decline for nine hours." "On the other hand, the entire rise is very rapid, most of it being confined within a two hours' interval." And again:

"First, the rise, which is very uniform and rapid, requires over two and a half hours, but is mostly comprised in half of that interval.

"Second, the maximum light . . . is not constant at different epochs, but has a range of at least $0^m{\cdot}2$. . .

"Third, the decline is normal until [$0^d{\cdot}26$] is reached, and on several times considerable increase of light has occurred between [$0^d{\cdot}22$] and [$0^d{\cdot}32$], amounting to more than $0^m{\cdot}2$, and at other times it has been normal. A comparatively sharp minimum occurs at [$0^d{\cdot}385$], followed by a sharp secondary maximum, which at times rises to $9^m{\cdot}2$ . . ., at other times it is not quite so pronounced. A rapid decline from this secondary maximum is followed by a flat minimum," at [$0^d{\cdot}53$]. [The times have been adjusted as well as can be judged to apply to our curve.]

11. The extreme range of photographic magnitude is about $1^m{\cdot}1$, or about half as much again as the visual range. This difference is normally found, and seems to point to a temperature change as the proximate cause of the varying radiation. For the rest, there would seem to be a rough correspondence between the results of the two classes of observation in general and considerable discrepancies in detail. Beyond this little can be said. The discrepancies may be due (*a*) to uncertainties in the observations on

either side; (*b*) to real and permanent differences corresponding to the different effective ranges in the wave-length employed; and (*c*) to periodic, secular or irregular changes in the star which will be difficult to detect with certainty. There seems nothing in the photographic observations of the past few weeks to suggest that any serious effects of the latter class have been in operation. But it may be the best way of solving this question to repeat the work for comparison with the present results after the lapse of a certain interval of time.

Dunsink Observatory:
1913 *January* 7.

Note added 1913 *January* 27.

The result of applying harmonic analysis to Sperra's visual light curve gives the following formula:—

$$m = 9^{\cdot}30 + {}^{\cdot}28 \sin(\theta + 235^{\circ}{\cdot}7) + {}^{\cdot}12 \sin(2\theta + 234^{\circ}{\cdot}5) + {}^{\cdot}07 \sin(3\theta + 277^{\circ}{\cdot}2) + {}^{\cdot}05 \sin(4\theta + 330^{\circ}{\cdot}8) + {}^{\cdot}02 \sin(5\theta + 288^{\circ}{\cdot}4) + {}^{\cdot}03 \sin(6\theta + 3^{\circ}{\cdot}6) + {}^{\cdot}01 \sin(7\theta + 60^{\circ}{\cdot}3) + {}^{\cdot}01 \sin(10\theta + 139^{\circ}{\cdot}4) + {}^{\cdot}01 \sin(11\theta + 333^{\circ}{\cdot}4),$$

where the epoch has been adjusted by supposing that the visual magnitude 9·1 precedes the maximum by ·05 day. Comparison with the formula in § 7 shows at all events a general correspondence in the main terms. As regards the feature alluded to in § 8, we must write the fifth, sixth, and seventh terms more accurately in order to bring out the point, thus—

$$+ {}^{\cdot}016 \sin(5\theta + 288^{\circ}{\cdot}4) + {}^{\cdot}027 \sin(6\theta + 3^{\circ}{\cdot}6) + {}^{\cdot}013 \sin(7\theta + 60^{\circ}{\cdot}3),$$

or by an imperceptible adjustment—

$$+ {}^{\cdot}014 \sin(5\theta + 288^{\circ}{\cdot}4) + {}^{\cdot}028 \sin(6\theta + 3^{\circ}{\cdot}6) + {}^{\cdot}014 \sin(7\theta + 60^{\circ}{\cdot}3),$$

which can be written—

$$+ {}^{\cdot}028 \sin(6\theta + 3^{\circ}{\cdot}6) - {}^{\cdot}028 \sin(6\theta - 5^{\circ}{\cdot}6) \cos(\theta + 66^{\circ}{\cdot}0).$$

In this form the correspondence of these terms in the photographic and visual observations becomes self-evident. In the latter we have at one point ($\theta = 114^{\circ}$) two variations which combine to produce an amplitude of $0^{m}{\cdot}056$ in one-sixth of the whole period, while at another point ($\theta = 294^{\circ}$) these variations destroy one another. The visual effect is only one-half of the photographic effect, and the possibility of detecting so slight a ripple on the visual light curve is a remarkable testimony to the excellence of Mr. Sperra's visual observations and the practical efficiency of the periodic analysis.

To the causes suggested in § 11 for the apparent discrepancies between the results of the two classes of observation may be added yet another. May not the irregularity observed in the behaviour of the star be merely an apparent effect arising from a want of constancy in the visual standards of comparison?

On the Motions and Distances of the Bright Stars of the Types B–B5. (Stellar Motions, No. 4.) By H. C. Plummer.

1. In a paper published a year ago (*M.N.*, lxxii. p. 170) the following figures were quoted from an important memoir by Dr. Campbell on the motions of the stars (*L.O.B.*, 196):

Residual Velocities in terms of Galactic Latitudes.

	±90°–±60°.		±60°–±30°.		±30°–±0°.	
Class.	No.	km.	No.	km.	No.	km.
B	7	5·4	27	5·6	191	7·1
A	18	5·6	61	9·2	98	13·0

For the class A stars we see at a glance such a notable progressive decline in the radial component of the velocities (corrected for the effect of the Sun's motion) in the extra-galactic regions that it is immediately suggested that these stars are moving very approximately parallel to the plane of the Milky Way. So close does the parallelism appear that it seemed worth while to suppose it absolute. The results which followed from this hypothesis have been described fully (*L.O.B.*, 212). They appeared sufficiently interesting to make it desirable to extend the application of the method to other classes of stars. Since it had been suggested that the stars of types B8 and B9, by virtue of their proper motions, should be connected with the class A stars rather than with those of the earlier B types, it was natural to extend the study to these in the first instance. The results of this examination have been published (*M.N.*, lxxii. p. 555), and may be considered to have justified the expectation based on the nature of their proper motions. But their number (45) is small, and they constitute only one-fifth of the total of stars of class B for which the radial motions have been published in a collected form by Dr. Campbell (*L.O.B.*, 195).

2. The remaining 180 stars of the earlier B types now deserve similar treatment. At first sight the evidence given by the above figures for a like tendency in the motions is much weaker than for the class A stars. In the intermediate zones we should expect an average radial velocity of 5·3 km., and in the outside zones about 2·5 km. The latter expectation is not borne out. Yet the number of stars is here too small to give the contradiction serious weight. On the other hand, the marked feature of these stars is their general close proximity to the Milky Way. It would be unnatural if this were a fortuitous circumstance true only at a particular epoch. On the contrary, it is much more reasonable to suppose that the arrangement is more or less permanent, requiring the motions as well as the positions to be nearly in a plane, and this presumption is unaffected by the evidence of a few stars situated at a considerable distance from that plane. Hence it will not be surprising if, as the event proves, the result of applying the same provisional hypothesis is apparently quite as satisfactory for the

stars of earlier type, B–B5, as for those of later type, B8–A8, although the investigation began with the latter class of stars for the reason explained. It may be noted that Dr. Campbell himself expressed the opinion (*L.O.B.*, 196, addendum): "The preference of the class B stars for motion in and parallel to the plane of the Milky Way may be even stronger than in the case of class A stars."

3. The method followed has been fully described (*L.O.B.*, 212). As before, it has been assumed that the component of the Sun's motion normal to the Milky Way is 6·50 km. per sec., the galactic pole being taken at (192°, +27°). This value corresponds to Campbell's determination of the solar motion, 16·8 km. per sec. towards (270°, +30°), for the class A stars. Thus all the available stars of the classes B and A will have been submitted to a uniform treatment. Otherwise it may seem more natural to have adopted Campbell's solution for stars of the type B–B5, namely 20·7 km. per sec. towards (270°·5, +34°·3). The event suggests (see § 6) that while uniformity would have been sacrificed, the change would have been more apparent than real. It would, however, have changed the solar component from 6·50 to 8·33 and would certainly have affected the individual results.

On the other hand, Campbell's determination of the systematic error which must be subtracted from the observed radial velocities, +4·70 km. per sec. for the present stars, has been adopted, and the corresponding correction applied.

4. The material has been taken directly from the *Preliminary General Catalogue* of Boss in what concerns the proper motions, and from Campbell's memoir (*L.O.B.*, 195) in what concerns the radial velocities and supplementary data, the latter following the *Revised Harvard Photometry* with very slight modifications. The results are given in Table I. Here the first column gives the P.G.C. number of the star, and the second column its name; when a recognised name is wanting, the constellation is mentioned as a means of indicating the region of the sky to which the star belongs. The third and fourth columns give the type of spectrum and visual magnitude, in the main according to the R.H.P. system. The approximate co-ordinates of each star for 1900·0 will be found in the sixth and seventh columns. The proper motions in the eighth and ninth columns are taken unaltered from the P.G.C. The tenth column gives the observed, uncorrected radial velocity V in km. per sec., as shown in Campbell's list (*L.O.B.*, 195). The other columns of the table contain calculated results. The eleventh column gives the deduced parallax under the heading ϖ, and the last three columns give the corresponding components of velocity relative to the Sun in km. per sec. in three fixed rectangular directions, viz. (*u*) towards the First Point of Aries, (*v*) towards the point (6^h, 0°), and (*w*) towards the North Pole. The absolute magnitude (m_0) defined by the formula

$$m_0 = m + 5 \log (\varpi / 0''{\cdot}01),$$

TABLE I.

P.G.C.	Star.	Type.	m.	m_0.	R.A.	Decl.	μ_α.	μ_δ.	V.	ϖ.	u.	v.	w.
					h m	° ′	s	″		″			
27	γ Pegasi	B2	2·9	2·4	2 1	+14 38	·0000	− ·013	+ 6·5	·0079	+ 3 7	0·0	− 7·1
122	ζ Cassiopeiæ	B2	3·7	3·0	7 51	+53 21	+ ·0023	− ·009	+ 3·0	·0071	+ 1·9	+ 14·1	− 4·9
123	π Andromedæ	B3	4·4	4·3	7 53	+33 10	+ ·0017	− ·009	+ 8·8	·0098	+ 4·3	+ 11·1	− 1·4
175	ν ,,	B3	4·4	3·0	11 4	+40 32	+ ·0017	− ·021	− 23·9	·0054	− 12·8	+ 15·0	− 32·7
199	γ Cassiopeiæ	Bp	2·2	− 2·5	12 40	+60 11	+ ·0040	− ·002	− 3	·0012	- 23·5	+119·2	− 10·7
212	α Sculptoris	B5	4·4		13 27	− 29 54	+ ·0006	+ ·001	+11	neg.			
384	ϕ Persei	Bp	4·2	3·6	24 21	+ 50 11	+ ·0029	− ·018	0	·0076	− 2·0	+ 18·2	− 10·8
419	ϵ Cassiopeiæ	B5	3·4	2·2	26 48	+63 11	+ ·0057	− ·017	− 9	·0059	− 8·6	+ 30·6	− 18·4
563	κ Eridani	B5	4·4	1·3	35 50	−48 9	+ ·0012	− ·013	+30·4	·0024	− 15·2	+ 18·0	− 36·1
604	δ Ceti	B2	4·0		38 35	− 0 6	+ ·0007	+ ·001	+10	neg.			
627	π ,,	B5	4·4		39 50	− 14 17	− ·0005	− ·014	+13	,,			
679	λ ,,	B5	4·7		43 35	+ 8 31	+ ·0006	− ·006	+14	,,			
780	− Persei	B3	4·9	1·6	50 14	+48 43	+ ·0025	− ·020	+ 8	·0022	− 18·6	+ 59·9	− 25·6
839	40 ,,	B2	5·0	0·9	54 1	+33 39	+ ·0008	− ·011	+ 3	·0015	− 15·0	+ 32·8	- 29·7
844	38 ,,	B1	3·9	5·9	54 31	+31 58	+ ·0008	− ·024	+18·5	·0255	+ 6·6	+ 12·6	+ 3·5
852	17 Tauri	B5	3·8	7·0	54 43	+23 48	+ ·0014	− ·050	+14·6	·0444	+ 4·8	+ 10·3	− 0·9
856	19 ,,	B5	4·4	5·6	54 49	+24 9	+ ·0008	− ·048	+ 3	·0172	− 0·2	+ 4·9	− 12·8
860	20 ,,	B5	4·0	4·2	54 58	+24 3	+ ·0021	− ·045	+ 7	·0112	− 4·3	+ 15·1	− 16·5
865	23 ,,	B5	4·2	5·4	55 6	+23 38	+ ·0017	− ·054	+ 6	·0177	− 1·1	+ 9·3	− 12·7
869	η ,,	B5	3·0	6·2	55 23	+23 48	+ ·0014	− ·048	+15	·0429	+ 4·8	+ 10·7	− 0·7
874	30 ,,	B3	5·0		55 42	+10 50	+ ·0024	− ·022	+17	(·191)			
894	ζ Persei	B1	2·9	3·1	56 58	+31 35	+ ·0010	− ·017	+20·4	·0109	+ 4·7	+ 17·5	+ 1·9

920	λ Tauri	B3	(3·8)	4·6	58 47	+12 12	−·0004	−·014	+10	·0146	+ 4·8	+ 4·3	− 3·3
981	μ ,,	B5	4·3		62 32	+ 8 39	+·0019	−·020	+18	(1·03)			
1003	53 Persei	B3	4·9	4·3	63 35	+46 16	+·0023	−·038	+ 3	·0075	− 6·3	+ 21·1	−17·8
1066	δ Cæli	B3	5·2		66 57	−45 10	−·0003	−·012	+16·0	neg.			
1079	ν Eridani	B2	4·1	1·1	67 50	− 3 33	·0000	−·002	+14	·0025	+ 3·4	+ 8·4	− 4·4
1139	9 Camelop.	B	4·4		71 2	+66 10	+·0012	+·005	+ 8	neg.			
1147	3 Orionis	B3	3·8		71 28	+ 5 26	−·0003	−·006	+23·3	,,			
1159	8 ,,	B3	3·9	5·4	72 16	+ 2 17	−·0002	−·003	+18	·0203	+ 4·7	+ 12·5	− ·02
1204	η Aurigæ	B3	3·3	4·3	74 53	+41 6	+·0027	−·075	+ 3	·0156	− 5·4	+ 15·6	−18·3
1262	τ Orionis	B5	3·7	8·1	78 11	− 6 57	−·0011	−·007	+18	·0753	+ 3·7	+ 12·7	− 2·1
1277	λ Leporis	B2	4·3	3·4	78 45	−13 17	·0000	+·003	+21	·0066	+ 3·2	+ 16·1	− 1·7
1284	22 Orionis	B3	4·6		79 10	− 0 29	−·0003	−·003	+28	neg.			
1301	η ,,	B1	3·4	2·2	79 52	− 2 29	+·0004	+·001	+35·5	·0058	+ 0·6	+ 31·2	− 0·5
1303	γ ,,	B2	1·7	3·8	79 57	+ 6 16	−·0005	−·019	+18	·0267	+ 3·7	+ 13·2	− 1·9
1314	ψ ,,	B2	4·7	4·9	80 24	+ 3 1	−·0003	−·013	+12·0	·0109	+ 3·2	+ 7·2	− 5·3
1315	114 Tauri	B3	4·8		80 24	+21 51	+·0008	−·013	+16·5	neg.			
1339	δ Orionis	B	2·5	−3·5	81 43	− 0 22	+·0001	−·003	+23·1	·0006	− 8·6	+ 19·7	−22·8
1340	υ ,,	B	4·6	3·4	81 46	− 7 23	+·0002	−·012	+17·0	·0057	− 0·9	+ 11·2	−11·4
1361	− ,,	B1	4·7	4·1	82 32	− 6 5	+·0001	+·004	+29	·0076	+ 2·3	+ 24·4	− 0·1
1370	ε ,,	B	1·8	1·4	82 47	− 1 16	·0000	−·002	+24·5	·0085	+ 2·5	+ 19·6	− 1·6
1375	ζ Tauri	B3	3·0	3·3	82 55	+21 5	+·0002	−·028	+16·4	·0113	+ 0·7	+ 15·2	− 6·8
1396	126 ,,	B3	4·9	3·8	83 53	+16 29	+·0009	−·028	+32	·0059	− 6·9	+ 33·5	−13·9
1398	ζ Orionis	B	2·0		83 56	− 2 0	+·0005	−·007	+17·5	neg.			

TABLE I.—*continued.*

P.G.C.	Star.	Type.	m.	m_0.	R.A.	Decl.	μ_α.	μ_δ.	V.	ϖ.	u.	v.	w.
					h m	° ′	s	″		″			
1399	– Orionis	B3	5·0		83 57	– 1 11	– ·0008	– ·008	+26·1	(·167)			
1435	κ ,,	B	2·2		85 45	– 9 42	+ ·0002	– ·005	+21	neg.			
1467	λ Columbæ	B5	4·9	5·9	87 22	– 33 49	+ ·0001	+ ·028	+25	·0159	+ 0·6	+ 21·5	– 4·4
1469	ϵ Doradus	B5	5·2		87 30	– 66 56	– ·0041	+ ·011	+18	neg.			
1490	γ Columbæ	B3	4·4		88 30	– 35 18	– ·0003	+ ·002	+23	,,			
1507	62 Orionis	B2	4·7		89 30	+20 8	+ ·0006	– ·013	+21	,,			
1601	ζ Canis Maj.	B3	3·1		94 7	– 30 1	+ ·0006	+ ·001	+24	,,			
1609	β ,,	B1	2·0		94 37	– 17 54	– ·0005	·000	+33·7	,,			
1634	10 Monocerotis	B3	5·0		95 45	– 4 42	– ·0002	+ ·014	+28	,,			
1641	λ Canis Maj.	B5	4·5		96 7	– 32 31	– ·0022	+ ·016	+25	,,			
1660	ξ^1 ,,	B1	4·4		96 55	– 23 21	+ ·0006	+ ·001	+30	,,			
1761	κ ,,	B2*p*	3·8	3·1	101 32	– 32 24	– ·0008	+ ·001	+ 8	·0072	+ 5·9	+ 4·4	– 1·2
1793	ι ,,	B5	4·4		102 55	– 16 55	– ·0001	+ ·011	+40·0	neg.			
1804	ϵ ,,	B1	1·6		103 40	– 28 50	+ ·0001	– ·001	+29·2	,,			
1817	24 ,,	B5*p*	3·1		104 43	– 23 41	– ·0005	– ·006	+49	(·275)			
1819	γ ,,	B5	4·1	3·6	104 49	– 15 29	– ·0001	– ·014	+28·5	·0078	– 4·4	+ 20·2	– 14·6
1845	A Puppis	B3	4·8	5·7	106 22	– 39 30	– ·0011	+ ·003	+19	·0154	+ 0·5	+ 12·3	– 8·4
1877	ω Canis Maj.	B3*p*	3·8	3·7	107 41	– 26 36	– 0003	– ·008	+29	·0097	– 4·2	+ 19·6	– 14·4
1910	v^2 Puppis	B3	5·1	6·4	108 46	– 36 34	– ·0009	– ·013	+18	·0179	– 0·1	+ 9·1	– 10·7
1934	η Canis Maj.	B5*p*	2·4	2·8	110 2	– 29 6	– ·0007	+ ·004	+40·3	·0118	– 7·5	+ 31·2	– 15·9
2017	d^1 Puppis	B5	4·9	7·1	113 59	– 38 5	– ·0019	– ·006	+24·1	·0276	– 2·6	+ 15·2	– 13·0
2070	P ,,	B	4·2	5·4	116 33	– 46 7	– ·0011	– ·009	+20·5	·0177	– 1·4	+ 9·6	– 13·1

2111	χ Carinæ	B3	3·6	5·9	118 34	−52 43	−·0037	+·017	+19·6	·0286	− 0·5	+ 12·6	−10·2
2226	B Velorum	B2	4·9	5·7	124 52	−48 10	−·0017	−·002	+19	·0144	− 0·6	+ 10·6	−11·1
2266	A ,,	B5	5·5	5·2	126 29	−47 36	−·0012	−·005	0	·0087	+ 8·4	− 0·3	+ 1·6
2325	σ ,,	B3	3·7	2·4	129 21	−52 34	−·0018	+·012	+18	·0054	+ 0·7	+ 21·8	− 4·2
2341	− ,,	B5	5·0	6·4	129 53	−52 45	−·0029	+·002	+19·4	·0189	− 0·9	+ 11·4	−11·4
2342	α Pyxidis	B2	3·7	1·2	129 54	−32 50	·0009	+·006	+17·4	·0032	+ 3·0	+ 22·7	+ 0·6
2428	− Velorum	B5	5·5	7·1	134 54	−41 28	−·0041	−·002	+32	·0207	− 6·8	+ 21·7	−18·4
2457	E Carinæ	B3p	4·9	3·9	136 12	−70 8	−·0012	+·005	+26	·0064	− 4·6	+ 10·7	−18·8
2467	− Velorum	B5	5·0	3·9	136 52	−44 28	−·0013	·000	+35	·0061	− 8·4	+ 22·7	−21·2
2473	α Carinæ	B3	3·6	6·4	137 5	−58 33	−·0052	−·005	+23·3	·0368	− 3·1	+ 10·1	−16·2
2477	i ,,	B3	4·2	6·7	137 15	−61 54	−·0067	+·005	+16	·0313	+ 0·5	+ 9·3	− 9·6
2526	κ Velorum	B3	2·6	3·5	139 45	−54 35	−·0023	−·005	+21·9	·0150	− 2·5	+ 10·4	−14·9
2581	h Carinæ	B5	4·2	−0·3	142 53	−58 47	−·0018	+·011	+21·7	·0013	− 3·5	+ 67·9	+ 6·6
2600	κ Hydræ	B3	5·0	4·6	143 53	−13 53	−·0018	−·016	+24	·0082	− 4·3	+ 22·1	−13·7
2674	ϕ Velorum	B5	3·7	4·3	148 20	−54 6	−·0025	−·006	+14·4	·0131	+ 0·8	+ 8·8	− 9·1
2755	J ,,	B5p	4·6	3·8	154 18	−55 32	−·0021	·000	+ 9	·0070	+ 3·1	+ 12·0	− 3·6
2792	30 Sextantis	B5	5·0	5·6	156 18	− 0 7	−·0031	−·028	+14	·0132	− 1·8	+ 19·0	−10·0
2811	p Carinæ	B5p	3·6	2·4	157 7	−61 10	−·0035	+·007	+24	·0058	− 5·1	+ 24·6	−14·2
2860	− ,,	B3p	5·4	6·0	159 42	−58 42	−·0002	−·020	0	·0134	+ 8·2	− 2·4	+ 0·4
2862	θ ,,	B	3·0	−0·4	159 51	−63 52	−·0033	+·009	+16	·0020	− 4·8	+ 55·5	− 1·0
2889	δ^2 Chamæl.	B3	4·6	9·8	161 13	−80 1	−·0183	−·004	+22	·1119	− 2·0	+ 2·8	−17·1
3162	− Centauri	B5	4·8	3·4	180 44	−50 6	−·0031	−·005	+16·4	·0053	− 4·4	+ 26·7	−11·9
3176	ρ ,,	B3	4·2	4·7	181 36	−51 49	−·0047	−·022	+28	·0124	− 8·3	+ 16·4	−23·5

TABLE I.—*continued.*

P.G.C.	Star.	Type.	m.	m_0.	R.A.	Decl.	μ_α.	μ_δ.	V.	ϖ.	u.	v.	w.
					h		s	"		"			
3187	δ Crucis	B3	3·1	4·0	182 27′	−58 12′	−·0055	−·019	+25	·0148	− 6·1	+ 13·7	−20·5
3200	ζ ,,	B3	4·3	5·7	183 15	−63 27	−·0069	−·019	+19·9	·0189	− 3·2	+ 11·5	−15·7
3237	α^1 ,,	B1	1·6	3·6	185 16	−62 33	−·0051	−·031	+ 7	·0251	+ 3·5	+ 7·0	− 4·7
3289	α Muscæ	B3	2·9	4·3	187 48	−68 35	−·0065	−·021	+13·5	·0195	+ 0·4	+ 8·8	−10·1
3324	− Crucis	B3	4·9	6·8	190 10	−55 56	−·0045	−·040	+18·2	·0237	− 2·3	+ 7·3	−15·7
3328	β ,,	B1	1·5	3·0	190 28	−59 9	−·0062	−·028	+13	·0195	− 0·6	+ 11·7	−10·6
3358	μ^1 ,,	B3	4·3	3·9	192 11	−56 38	−·0040	−·013	+13·2	·0082	− 2·5	+ 19·0	−11·2
3359	μ^2 ,,	B3*p*	5·5	5·9	192 11	−56 38	−·0026	−·017	+ 7	·0118	+ 2·5	+ 9·3	− 5·7
3476	α Virginis	B2	1·2	2·7	199 59	−10 38	−·0028	−·036	+ 1·6	·0196	+ 1·0	+ 11·0	− 8·0
3521	ε Centauri	B1	2·6	3·4	203 23	−52 57	−·0034	−·027	+ 6	·0147	+ 1·7	+ 11·5	− 6·3
3564	ν ,,	B2	3·5	3·6	205 53	−41 11	−·0030	−·025	+ 6	·0106	− 0·9	+ 16·4	− 9·3
3565	μ ,,	B2*p*	3·3	2·2	205 54	−41 59	−·0020	−·018	+12·6	·0061	− 4·4	+ 17·3	−15·8
3566	η Ursæ Maj.	B3	1·9	5·3	205 54	+49 49	−·0121	−·021	− 6	·0489	− 0·2	+ 12·6	− 9·5
3577	*k* Centauri	B5	4·7	4·7	206 31	−32 30	−·0036	−·039	+14·1	·0098	− 7·9	+ 20·7	−21·0
3586	*h* ,,	B5	4·8	4·3	206 52	−31 26	−·0014	−·021	+ 8	·0078	− 1·5	+ 11·4	−12·6
3602	φ ,,	B3	4·0	3·6	208 3	−41 37	−·0024	−·020	+ 5·3	·0082	− 0·9	+ 17·2	− 9·1
3603	υ^1 ,,	B3	4·2	5·2	208 8	−44 19	−·0031	−·032	+ 4	·0160	+ 1·6	+ 12·0	− 6·3
3615	β ,,	B1	0·9	2·0	209 11	−59 53	−·0035	−·032	+12	·0168	0·0	+ 8·5	−10·8
3621	χ ,,	B3	4·5	5·1	209 59	−40 42	−·0016	−·034	+12·4	·0132	− 1·4	+ 6·7	−14·3
3670	υ ,,	B5	4·4	4·1	213 20	−55 56	−·0029	−·021	+ 3·5	·0088	+ 1·2	+ 16·5	− 5·3
3688	ω ,,	B5	4·6	5·5	214 13	−39 3	−·0024	−·040	+ 9·2	·0149	− 1·3	+ 9·9	−12·7
3699	τ^1 Lupi	B3	4·6	10·0	214 56	−44 46	−·0009	−·029	−16·6	·1199	+12·8	+ 9·4	+14·2

3716	σ Lupi	B2	4·6		216 28	−50 1	−·0054	−·013	− 0·6	neg.				
3724	η Centauri	B3*p*	2·6	3·7	217 17	−41 43	−·0030	−·035	0	·0166	+ 2·3	+ 13·8	− 4·3	
3745	α Lupi	B2	2·9	3·1	218 49	−46 58	−·0021	−·028	+ 8	·0108	− 0·7	+ 11·6	−10·8	
3783	o ,,	B5	4·5	4·5	221 17	−43 10	−·0032	−·035	+ 7·2	·0099	3·8	+ 19·0	−13·9	
3815	β ,,	B2*p*	2·8	4·2	223 0	−42 44	−·0043	−·051	0	·0194	+ 0·8	+ 16·6	− 6·0	
3818	κ Centauri	B3	3·4	3·7	223 10	−41 42	−·0015	−·032	+10	·0116	− 1·2	+ 8·3	−13·3	
3892	− Lupi	B4	5·8	4·6	228 6	−40 25	−·0022	−·032	+21	·0057	−12·3	+ 17·5	−30·8	
3905	ϵ ,,	B3	3·7	2·5	228 58	−44 20	−·0015	−·023	+14	·0059	− 5·7	+ 13·3	−19·8	
3954	d ,,	B3	4·8	6·3	232 15	−44 37	−·0006	−·039	+ 5	·0199	+ 2·7	+ 5·9	− 6·8	
3991	4 ,,	B5	4·8	3·1	234 5	−34 23	−·0026	−·037	+12	·0046	−17·6	+ 31·6	−35·3	
4052	ρ Scorpii	B3	4·0	4·0	237 41	−28 55	−·0010	−·030	+ 3·2	·0099	− 0·9	+ 10·3	−11·8	
4076	− Lupi	B5	5·0	4·0	239 11	−38 19	−·0022	−·035	+ 5	·0063	− 8·5	+ 23·9	−20·9	
4093	ω^1 Scorpii	B2	4·1		240 14	−20 24	−·0005	−·033	−11	(·307)				
4156	− Normæ	B5	5·5	5·7	243 45	−49 20	−·0011	−·031	+ 1	·0108	+ 1·4	+ 13·6	− 6·1	
4162	τ Herculis	B5	3·9	2·2	244 11	+46 33	−·0012	+·030	−13·8	·0045	+ 3·8	+ 37·9	+ 8·4	
4180	ϵ Normæ	B4	4·7	−0·5	244 58	−47 20	−·0006	−·008	+ 7	·0009	−16·3	+ 39·2	−29·5	
4190	− ,,	B1*p*	5·5		245 37	−46 1	−·0015	−·010	−21	neg.				
4218	τ Scorpii	B	2·9	3·5	247 25	−28 1	−·0008	−·037	+ 1·5	·0131	0·0	+ 9·9	−10·4	
4249	− Aræ	B3	5·9	6·5	249 27	−58 19	·0000	−·030	0	·0129	+ 4·2	+ 11·1	− 1·8	
4281	μ^2 Scorpii	B2	3·6	0·6	251 23	−37 51	−·0016	−·028	+ 1·7	·0025	−22·8	+ 44·5	−40·0	
4287	ζ^1 ,,	B1*p*	4·9	5·6	251 44	−42 12	+·0005	−·019	−27	·0138	+10·5	+ 25·9	+16·5	
4288	− ,,	B	5·3	3·4	251 45	−41 38	−·0003	−·012	−18	·0042	+ 4·5	+ 25·9	+ 4·9	
4334	k ,,	B1*p*	4·9	2·7	254 34	−33 59	+·0006	+·001	+ 8·6	·0037	+ 8·2	− 6·4	− 1·1	

TABLE I.—*continued.*

P.G.C.	Star.	Type.	m.	m_0.	R.A.	Decl.	μ_α.	μ_δ.	V.	ϖ.	u.	v.	w.
					h m	° ′	s	″		″			
4368	ζ Draconis	B5	3·2	2·6	257 7	+65 50	−·0021	+·020	−14·7	·0077	− 3·5	+ 20·5	−12·6
4388	68 Herculis	B3	(5·0)	4·7	258 24	+33 12	−·0016	−·013	−21·2	·0087	− 7·2	+ 19·6	−20·1
4399	θ Ophiuchi	B3	3·4	4·0	258 58	−24 54	−·0001	−·031	− 0·9	·0132	+ 1·4	+ 9·7	− 7·7
4429	υ Scorpii	B3	2·8	3·8	260 59	−37 13	−·0002	−·042	+17	·0162	− 1·1	− 2·2	−17·3
4431	α Aræ	B3*p*	3·0	3·4	261 2	−49 48	−·0034	−·084	+ 2	·0122	− 8·5	+ 28·4	−19·1
4439	λ Scorpii	B2	1·7	2·1	261 42	−37 2	−·0003	−·036	+ 3	·0121	0·0	+ 9·9	−10·2
4479	ι Herculis	B3	3·8	3·2	264 10	+46 4	−·0008	−·002	−16·1	·0076	− 3·8	+ 14·0	−15·8
4548	67 Ophiuchi	B5*p*	3·9	3·4	268 55	+ 2 56	+·0001	−·014	− 4·0	·0078	+ 1·1	+ 8·2	− 8·9
4565	θ Aræ	B1	3·9	−0·2	269 43	−50 6	−·0012	−·028	+ 2·8	·0015	−36·5	+ 70·0	−55·9
4590	102 Herculis	B2	4·3	5·8	271 7	+20 48	−·0001	−·017	−12	·0200	− 0·6	+ 14·2	− 9·7
4604	μ Sagittarii	B5	4·0	2·2	271 57	−21 5	+·0003	−·005	− 7	·0043	+ 4·2	+ 13·1	− 0·9
4612	15 ,,	B	5·4	2·4	272 17	−20 45	+·0001	−·005	− 6	·0026	+ 2·1	+ 13·4	− 4·9
4657	α Telescopii	B3	3·8	3·0	274 53	−46 1	−·0010	−·052	− 0·5	·0069	− 9·7	+ 28·7	−21·2
4734	− Sagittarii	B3	4·8	5·5	279 24	−35 44	·0000	−·053	+ 1·4	·0136	− 2·2	+ 13·3	−13·1
4776	β^1 Lyræ	B2*p*	(3·4)	3·1	281 36	+33 15	+·0003	−·007	− 7·8	·0085	+ 0·4	+ 8·6	−10·1
4784	σ Sagittarii	B3	2·1	3·7	282 16	−26 25	+·0006	−·066	− 1	·0209	− 0·7	+ 11·9	−10·8
4792	− Cor. Austr.	B5	5·4	6·9	282 28	−37 28	+·0019	−·017	+ 6	·0203	+ 4·9	+ 2·5	− 4·0
4897	η Lyræ	B3	4·5	0·6	287 35	+38 58	·0000	−·003	− 9	·0017	− 1·6	+ 5·0	−15·3
4906	1 Vulpeculæ	B5	4·6	0·6	287 59	+21 13	·0000	−·004	− 7	·0015	− 2·0	+ 6·2	−15·6
4942	3 ,,	B5	4·9	3·1	289 41	+26 4	−·0002	−·015	−12·2	·0043	− 5·5	+ 6·5	−22·1
4949	2 Cygni	B2	4·9	3·0	290 3	+29 26	+·0007	+·010	−18	·0043	+ 0·9	+ 27·2	− 1·5
4992	8 ,,	B3	4·8		292 1	+34 14	−·0002	−·003	−21·8	neg.			

5004	ι Aquilæ	B5	4 3	0·1	292 53	− 1 31	− ·0003	− ·017	-26	·0015	−26·0	+ 23·9	−54·4
5102	22 Cygni	B3	4·9		298 4	+38 13	− ·0005	− ·010	−35·0	(·00007)			
5190	− Vulpeculæ	B3	4·8		302 45	+25 17	− ·0002	− ·002	−10	neg.			
5223	α Pavonis	B3	2·1		304 26	−57 3	+ ·0005	− ·086	+ 2·0	(·00003)			
5265	ω Cygni	B3	4·9	4·3	306 44	+48 37	+ ·0009	+ ·004	−32	·0076	−11·2	+ 24·3	−25·9
5272	ε Delphini	B5	4·0	3·2	307 7	+10 58	+ ·0006	− ·026	−22	·0069	− 8·9	+ 21·9	−22·6
5361	55 Cygni	B2	4·9	2·7	311 23	+45 45	+ ·0003	− ·004	− 3·9	·0037	+ 1·5	+ 4·4	− 9·7
5375	57 ,,	B3	4·7	3·8	312 26	+44 1	+ ·0016	+ ·006	−16·2	·0067	− 3·1	+ 21·6	−11·5
5469	σ ,,	B5	4·3	−2·4	318 22	+38 59	− ·0004	− ·006	− 7	·0005	− 9·7	− 56·3	−55·8
5471	υ ,,	B3*p*	4·4	6·4	318 27	+34 29	+ ·0016	− ·021	+11	·0250	+ 8·1	− 2·1	+ 0·3
5532	β Cephei	B1	3·3	1·7	321 51	+70 7	+ ·0022	+ ·005	− 5	·0047	+ 0·7	+ 13·8	− 7·4
5563	9 ,,	B2	4·9	1·3	323 49	+61 38	+ ·0007	+ ·002	−12·5	·0019	− 2·9	+ 17·2	−12·8
5609	81 Cygni	B3	4·3	1·6	325 46	+48 51	+ ·0004	− ·003	−19·2	·0029	− 6·2	+ 12·2	−21·3
5762	31 Pegasi	B3*p*	4·9		334 9	+11 42	+ ·0003	+ ·005	+ 7·0	neg.			
5763	32 ,,	B5	4·9	3·1	334 11	+27 50	+ ·0004	− ·002	+ 9	·0044	+ 6·8	+ 3·1	+ 0·1
5764	2 Lacertæ	B5	4·7	3·7	334 13	+46 2	+ ·0019	·000	− 9·0	·0059	− 1·6	+ 18·5	− 9·9
5779	4 ,,	B5	4·6	1·4	335 7	+48 58	− ·0008	− ·011	−25·7	·0023	− 9·4	− 13·6	− 37·9
5933	ο Andromedæ	B3	3·6	3·7	344 20	+41 47	+ ·0021	− ·021	−16	·0106	− 6·0	+ 12·6	− 20·8
5939	β Piscium	B5	4·6	3·0	344 42	+ 3 17	+ 0007	− ·008	+ 2·3	·0047	+ 0·9	+ 10·7	− 8·2
5955	1 Cassiopeiæ	B	4·9		345 36	+58 53	+ ·0013	+ ·006	− 2·0	neg.			
6046	− ,,	B3	4·9		351 21	+58 0	+ ·0031	+ ·013	−14·8	,,			
6155	σ ,,	B2	4·9	3·2	358 29	+55 12	+ ·0013	− ·005	− 4	·0045	− 0·3	+ 11·8	− 10·2
6173	ζ Sculptoris	B5	5·0	1·3	359 18	−30 17	+ ·0020	− ·002	-	·0018	− 7·6	+ 68·0	− 1·2

or the magnitude of the star when placed at the distance corresponding to the parallax 0″·01, is given in the fifth column adjacent to that which contains the apparent visual magnitudes.

5. The total number of stars dealt with is 180. Of the deduced parallaxes 28 are negative (or 16 per cent.). Another 7 (or 4 per cent.) must be set aside either because they are too large or because they are too small. In some of these cases at least it would be more correct to regard the determination as illusory than as showing a very marked peculiar motion normal to the plane of the Milky Way (see § 11). Doubtless the parallax (″·120) of τ^1 Lupi (P.G.C. 3699) should also be rejected on this ground (see, however, § 7), and that (″·112) of δ^2 Chamæl. (P.G.C. 2889). But it is hard to draw any hard and fast line, and though they are almost certainly excessive, their rejection would imply the existence of a criterion which does not exist. There remain therefore 145 stars (or 80 per cent.) of which the parallaxes come out positive and, on the whole, reasonable in amount. This is by far the best result from the present point of view hitherto obtained, and fully bears out Dr. Campbell's conjecture quoted in § 2.

It is clear that few of the present class of stars have parallaxes exceeding 0″·05. There is little material for comparison with direct determinations of relative parallaxes, and the comparison would be without value.

6. Since the component of the solar motion, 6·50 km./sec., is based on the class A stars, the average motion of the class B stars is determined independently, without any assumption derived from the stars themselves beyond the primitive hypothesis of motion parallel to the Milky Way. The means of the components (u, v, w) for the 145 stars are:

$$u = -2{\cdot}20, \quad v = +16{\cdot}48, \quad w = -11{\cdot}82,$$

which, when reversed, give for the motion of the Sun relative to the stars of type B–B5:

$$R = 20{\cdot}40 \text{ km./sec. towards } A = 277^\circ 36', \quad D = +35^\circ 24'.$$

The most appropriate comparison is with Campbell's determination from the same class of stars (*L.O.B.*, 196):

$$R = 20{\cdot}7 \text{ km./sec., towards } A = 270^\circ{\cdot}5, \quad D = +34^\circ{\cdot}3,$$

where the position of the apex is derived from Boss's general solution from proper motion data. The resemblance is close and seems to justify the remark in § 3, that uniformity of treatment has caused no great effect in the mean. Other results obtained by the present method are, for the types B8 and B9:

$$R = 18{\cdot}2 \text{ km./sec. towards } A = 271^\circ{\cdot}2, \quad D = +27^\circ{\cdot}4;$$

and for the class A stars:

$$R = 13{\cdot}40 \text{ km./sec. towards } A = 260^\circ\ 32', \quad D = +24^\circ\ 41'.$$

It is at least conceivable that there is a real drift among the systems of different spectral type relative to one another. It is equally suggested by Dr. Campbell's results.

7. As the stars considered lie for the most part nearly on a great circle, they necessarily present the appearance of a ring. Whether their distribution is really of this character, or whether the stars are more or less uniformly distributed in a plane, is a most interesting question. The evidence may be thought inherently weak, but, such as it is, it points unmistakably to the definite conclusion that we are dealing with a plane distribution of quite remarkable uniformity in the neighbourhood of the Sun. The density is such that if a circle be drawn with its centre at the Sun and its radius corresponding to the parallax $0''{\cdot}02$, it contains 20 stars of the type B–B5. This gives one star within the distance $\varpi = 0''{\cdot}090$; there may be two (see § 5). Calculating the limiting parallax which should include 2 stars, 3 stars, and so on, we find the expectation fulfilled with remarkable fidelity, the numbers 3, 4, 7, 8, 13, 14, 15, 19, 20, as required by the law according to the square of the distance, being verified exactly. We next find the numbers:

Lim. ϖ	$''{\cdot}020$	$''{\cdot}019$	$''{\cdot}018$	$''{\cdot}017$	$''{\cdot}016$	$''{\cdot}015$	$''{\cdot}014$	$''{\cdot}013$	$''{\cdot}012$	$''{\cdot}011$
Expect:	20	22	25	28	32	36	42	48	56	72
Found:	20	25	27	31	35	39	44	52	56	61

Thus, as far as the distance corresponding to the parallax $0''{\cdot}012$, the distribution in a plane would seem to be sensibly uniform. This does not mean that the material is exhaustive within this range (it is not), but simply that it is adequately representative. Beyond this distance the numbers to be expected naturally increase very rapidly, while the numbers found do not. If we go as far as $\varpi = 0''{\cdot}001$, there should be on this scale some 10,000 stars, whereas we find only 142 (between $0''{\cdot}001$ and $0''{\cdot}002$ there are 9 stars instead of 8000). But this is scarcely surprising, and may be accounted for in two ways. Our material is limited by the fifth visual magnitude, and therefore beyond a certain distance only the stars whose intrinsic brightness is exceptional can be included. In the second place, the system may not extend to this distance, or at any rate its density may well be much less than in the neighbourhood of the Sun.

8. We next consider the relation between spectral type and the absolute magnitudes m_0 corresponding to the parallax $0''{\cdot}01$. The means for each subdivision of type are given in Table II.

TABLE II.

Type.	No. of Stars.	Mean m_0.	Type.	No. of Stars.	Mean m_0.
B	8	2·0	B3	46	4·6
B*p*	2	0·6	B3*p*	7	4·7
B1	10	2·9	B4	2	2·1
B1*p*	2	4·2	B5	41	3·9
B2	19	2·9	B5*p*	4	3·1
B2*p*	4	3·2			

These may be combined according to the two columns, and the results, together with those previously obtained for comparison, are given in Table III.

TABLE III.

Type.	No. of Stars.	Absolute Mag.	Light.
B–B2	45	2·7	832
B3–B5	100	4·2	209
B8–B9	30	4·4	174
A	56	5·4	69
A1–A3	37	6·3	30
A5–A8	19	7·6	9
Sun (G)	...	10	1

It may be well to repeat the qualification that the magnitudes are almost certainly too bright owing to the natural tendency to include in the observations distant stars of exceptional brilliance. The fourth column gives a measure of the light radiated by an average star of each type as compared with the Sun.

Seeliger's estimates of mean absolute magnitudes, reduced to the standard distance here adopted, are 4·7 for class B and 7·5 for class A (*A.N.*, 4617, p. 170).

9. The mean hypothetical parallaxes can be arranged according to certain ranges of apparent magnitude, and this is done in Table IV. The results are given for the types B–B2 and B3–B5, both separately and jointly. Here the stars P.G.C. 2889 and 3699 are omitted on account of the disturbing influence which their exceptionally large (and probably spurious) parallaxes would exercise. Then follow the results for the type B8–B9 (*M.N.*, lxxii. p. 561), and the class A stars (*L.O.B.*, 212, p. 36). The whole are then combined according to the number of stars in each group, so as to obtain results which apply to Type I. stars as a whole. For comparison the analogous results of Campbell (*L.O.B.*, 196, Table VII.) and Kapteyn (*Groningen Publ.*, 8, p. 28) are appended at the end.

TABLE IV.

B–B2	Mag.	1·6	2·5–3·5	3·5–4·5	4·5–5·5		All
	No.	8	12	12	13		45
	ϖ	″·0162	″·0087	″·0093	″·0061		″·0094
B3–B5	Mag.	2·1	2·5–3·5	3·5–4·5	4·5–5·5	5·8	All
	No.	3	12	42	39	2	98
	ϖ	″·0272	″·0168	″·0131	″·0101	″·0093	″·0127
B–B5	Mag.	1·8	2·5–3·5	3·5–4·5	4·5–5·5	5·8	All
	No.	11	24	54	52	2	143
	ϖ	″·0191	″·0128	″·0123	″·0091	″·0093	″·0117

TABLE IV.—*continued.*

B8–B9	Mag.	2·5–3·5	3·5–4·5	4·5–5·5	5·5–6·0	2·5–6·0
	No.	3	7	15	3	28
	ϖ	″·0380	″·0221	″·0148	″·0093	″·0185
A–A8	Mag.	2·5–3·5	3·5–4·5	4·5–5·5		2·5–5·5
	No.	12	41	56		109
	ϖ	″·0197	″·0229	″·0213		″·0217
B–A8	Mag.	2·5–3·5	3·5–4·5	4·5–5·5		2·5–5·5
	No.	39	102	123		264
	ϖ	″·0169	″·0172	″·0153		″·0163
Type I. (Campbell)		·0076	·0150	·0147		(·0137)
,, (Kapteyn)		·0201	·0151	·0113		(·0141)

The general conclusion from the whole material is that the stars of Secchi's Type I. with apparent magnitudes 3, 4, and 5, considered as a whole, are very thoroughly mixed in space. The distances now obtained approach Campbell's results for the fainter stars and Kapteyn's for the brighter. The dimensions of the whole system would appear to be slightly smaller than their numbers would suggest; but the difference is not very great, the average distance being about 200 light years instead of 234. This similarity in the mean is not borne out in detail. In particular, there is a wide discrepancy between the parallaxes given above for all the B–B5 stars (″·0117) and Campbell's value (″·0060). The reason seems clear enough. The latter has been found by equating the mean residual velocity in the line of sight and the mean cross proper motion. This is a legitimate method, if we may assume that the peculiar motions of the stars are random in direction. This ceases to be so when there is a tendency to move parallel to a certain plane. To take an extreme case, let us suppose that all the stars of the system lie in the galactic plane, that they are moving strictly in that plane, and that the apex of the Sun's motion is also in the same plane. The cross proper motions then vanish, and therefore the deduced parallax also. It is true that our present method would also break down in this case, but the solution would merely become indeterminate, not erroneous. These considerations tend to qualify, as regards the white stars, Campbell's conclusion that the universe of brighter stars is much larger than we had supposed.

10. Among the stars previously dealt with, there were six stars which we found reason to assign to that remarkable stream, discovered by Mr. B. Boss, which is moving relative to the Sun with a velocity of 95 km. per sec. Here again we find 4 stars which may with some plausibility be assigned to the same system. The details given in Table V. are based on the assumption that they do possess this total relative motion.

TABLE V.

P.G.C.	Star.	Type.	m.	m_0.	ϖ.	u.	v.	w.	i.
					″				°
199	γ Cassiopeiæ	Bp	2·2	−1·9	·0015	−19·0	+92·2	− 9·8	1·1
2581	h Carinæ	B5	4·2	−1·0	·0009	− 2·1	+93·7	+15·4	1·4
2862	θ ,,	B	3·0	−1·6	·0012	− 5·0	+94·6	+ 5·7	2·9
6173	ζ Sculptoris	B5	5·0	+0·6	·0013	− 8·3	+94·6	− 2·9	3·0

In the last column under i are given the inclinations to the plane of the Milky Way of the motions of the stars freed from the effect of the solar motion. They show the same close approach to parallel motion with the galactic plane as the set of stars previously found, the average deviation being in both cases about 2°·2. They also, like the others, appear to be exceptionally bright and distant, and their velocities in space are in marked contradiction to the law of equi-partition of energy. As they appear to constitute a proportion of about 1 in 40 of the bright stars of Type I. they deserve attention on this ground alone.

11. Hitherto no further attention has been given to those cases in which the parallax has come out negative. But the results given in Table I. possess one feature which attracts notice. A particularly unfavourable condition of things reveals itself in the neighbourhood of 6^h R.A. Thus, although we have only 28 negative parallaxes altogether, no fewer than 8 occur consecutively at this place. This seemed to demand further examination. Now it happens that the proper motions in this region are not very large, and very accurate values of the parallaxes are not required in order to get an approximate notion of the linear motions of the stars, these depending chiefly on the observed velocities in the line of sight. But from the material now collected (Table IV.), we can make a more or less shrewd conjecture of what the parallaxes ought to be according to the apparent magnitudes and the spectral types of the stars. If this is done, the velocity components can be calculated. Accordingly the 8 stars between P.G.C. Nos. 1469 and 1660 were selected for treatment in this way, together with Nos. 1793, 1804, and 1817, for the last of which a positive but excessively large parallax resulted. The results are given in Table VI. The headings of the columns explain themselves with the exception of the last, where under N is given the linear motion, corrected for the solar component 6·50, normal to the galactic plane. The fact that the mean of N is exactly zero happily corroborates the choice of this fundamental constant in our work. Moreover, the average of these residuals taken without sign is 3·7 km./sec. This figure is not likely to have been unduly depressed by the fact that the parallaxes are conjectural and not altered in any way in order to produce a particular result. Thus the unbiassed evidence of 11 *unfavourable* stars of type B–B5 is that the majority even of these are moving with velocities normal to the galactic plane below 3·7 km. per sec. It would be hard to imagine a more impressive proof of the general soundness of our provisional hypothesis, even

if we have also to bear in mind the extreme sensitiveness of our method of treatment to the effect of small disturbing causes.

TABLE VI.

P.G.C.	Star.	Type.	m.	ϖ. (assumed.)	u.	v.	w.	N.
				"				
1469	ϵ Doradus	B5	5·2	·0090	+13·1	+10·0	−10·0	−11·3
1490	γ Columbæ	B3	4·4	·0120	+ 1·9	+15·4	− 9·9	− 2·5
1507	62 Orionis	B2	4·7	·0065	− 6·0	+18·6	− 3·3	+ 6·8
1601	ζ Canis Maj.	B3	3·1	·0168	− 3·4	+17·0	− 9·4	+ 2·0
1609	β ,,	B1	2·0	·0100	+ 1·2	+27·8	− 8·9	− 3·7
1634	10 Monocerotis	B3	5·0	·0100	− 1·0	+23·8	+ 4·7	+ 0·8
1641	λ Canis Maj.	B5	4·5	·0115	− 1·1	+16·9	−10·6	− 0·4
1660	ξ ,,	B1	4·4	0075	− 8·0	+22·7	− 9·5	+ 5·0
1793	ι ,,	B5	4·4	·0115	− 7·3	+34·3	− 5·9	+ 3·8
1804	ϵ ,,	B1	1·6	·0200	− 5·4	+21·0	−12·2	+ 1·8
1817	24 ,,	B5p	3·1	·0168	− 8·3	+39·1	−19·4	− 2·3
				(Means)	− 2·21	+22·41	− 8·58	0·00

12. When we examine the velocity components which result from our empirical choice of parallaxes the chief peculiarity which strikes us is that there is no peculiarity about the motions of these stars. They appear to be absolutely normal for stars of their class. A discussion of the general question of stream motion, which can now be made to include all the available material for the first type stars, will be more conveniently reserved for another occasion. But attention may be drawn to the means at the foot of Table VI. The mean components (u, v, w), taken with reversed signs, give the motion of the Sun relative to this system of 11 "unfavourable" stars. The result is :

$$R = 24{\cdot}1 \text{ km./sec. towards } A = 275^\circ{\cdot}6, \quad D = +20^\circ{\cdot}9.$$

This need not be taken too seriously as a determination of the solar motion. It is mentioned simply because it gives a plain indication how absolutely the observed data for the early type stars are conditioned by the motion of the Sun, a conclusion which is strongly reinforced by the circumstances under which these stars presented themselves for special examination.

13. Although a detailed discussion of the systematic motions of the available stars has not yet been undertaken and the results to be obtained will apply to the first type only, it may not be out of place to indicate the bearing of our present order of ideas on the general problem of stellar motions. The suggestions must be regarded as tentative and provisional, but as such they accord well with the purely exploratory character of the work at its present stage. The fundamental fact of observation revealed by the researches of Kapteyn, Eddington, and others on the proper motions

of the stars is a certain quality of bipolarity, as it may be termed. The simplest physical conception by which this phenomenon can be accounted for is some form of two-stream theory. But we know well enough that this interpretation of the results is not a necessary one. They can equally be explained by Schwarzschild's uniaxal modification of the Maxwell-Boltzmann law of velocity distribution. The mathematical expression of this theory is ideally simple, and it lends itself admirably to the practical discussion of the observed data. But on physical grounds the idea of predominant mobility in a particular direction is not so easily apprehended as that of two streams.

Our present conception is as simple in a physical sense as the two-stream theory, but it stands in much closer relation with Schwarzschild's ellipsoidal hypothesis. We suppose that a considerable proportion of the stars are moving nearly parallel to the plane of the Milky Way. These constitute apparently a large fraction of the first type stars, and possibly a sensible fraction of the later type stars also. They may conveniently be called the galactic stars and, taken by themselves, are characterised by a velocity distribution which is nearly two-dimensional. There exist also stars, chiefly of the later types, whose velocities may be approximately random in direction. They may be called the non-galactic stars, without implying thereby any distinct dissociation from the galactic system, and their velocity distribution is roughly spherical. It is unnecessary to assume that either the two-dimensional or the three-dimensional distribution is actually symmetrical about the origin. But supposing for the moment that this is the case, we should have as the resultant of the two an approximately spheroidal distribution in which the shortest axis is the axis of symmetry, and is directed towards the pole of the Milky Way. It is clear that when a system so constituted is observed from a point which itself is moving in an independent direction, we shall find that quality of bipolarity which we need to explain. Whether such an hypothesis corresponds with the facts of observation in detail is a matter for verification.

At first sight there is an obvious inconsistency between this suggestion of a theory and Schwarzschild's hypothesis. Here the axis of symmetry is perpendicular to the Milky Way: Schwarzschild's axis of symmetry is directed towards a point $(273^\circ, -6^\circ)$ in the galactic plane. But the latter is the longest axis; the former is the shortest. Thus the positions of these two axes are in reality perfectly accordant on both theories, and the only question which separates them is concerned with the relative length of the third axis, which is perpendicular to both of those already considered. According to Schwarzschild, it is equal to the smaller component, while we should expect it to be more nearly equal to the larger component. But the point is of minor importance, and the latter conclusion may be evaded if we do not assume the plane velocity distribution to be symmetrical. On this question some light should be shed by the detailed examination of the velocity components

derived in the course of this work. The division of the stars into two classes, galactic and non-galactic, may seem as wide a departure from the simplicity of the unitary hypothesis as the two-stream theory, but it involves no difficulty on physical grounds, and something of the kind seems to be required by the facts. At all events, it is based on the motion of the Sun relative to the stellar system as an objective reality, and it attributes to the constitution of the Milky Way the origin of those properties of the stellar motions which we have come to recognise in recent years.

14. The contents of this paper may be summarised as follows:

§ 1. Connection of the present paper with earlier work on the same subject, with references.

§ 2. Reasons for extending the study by the same method to the stars of type B–B5 with some hope of success.

§ 3. Details of the method employed.

§ 4. Description of Table I. in which the data and results are given in full.

§ 5. Brief summary of apparent success and failure.

§ 6. Resulting motion of the Sun relative to the system compared with some other results previously obtained.

§ 7. Evidence for supposing that this system of stars is distributed in a plane with some approach to uniformity in the neighbourhood of the Sun.

§ 8. The relation between spectral type and absolute magnitudes (Tables II. and III.).

§ 9. The relation between hypothetical parallaxes and apparent visual magnitudes (Table IV.). Discrepancy with Campbell's mean parallax of the system. Invalidity of the method of cross motions.

§ 10. Attribution of four stars to the stream of high velocity discovered by B. Boss (Table V.).

§ 11. Reconsideration of a group of negative parallaxes. Result of assigning empirical parallaxes (Table VI).

§ 12. Evidence derived from the same group of stars of the preponderating influence of the solar motion on the observed data.

§ 13. Discussion of the relation between the present galactic hypothesis and the ellipsoidal hypothesis of Schwarzschild.

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